MODERN OPERATIVE SURGERY

THIRD EDITION

EDITED BY

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This third edition of
MODERN OPERATIVE SURGERY
is dedicated to
the memory of
the late
RUTHERFORD MORISON
of
Newcastle-upon-Tyne
Great clinician, master surgeon, inspiring teacher

PREFACE TO THE THIRD EDITION

It is only fair to all concerned that the difficulties of book production in wartime should be appreciated Harassing delays for which the enemy is mainly responsible have dogged the preparation of this third edition and it is a tribute to the House of Cassells that it has been possible to proceed with the publication in spite of first a serious fire and later total destruction of their premises

Since the last edition death has carried off the following valued contributors Mr C C Choyce Mr Arthur E Giles Mr J H Just Mr L Bathe Rawling and Sir John Thomson Walker and during the preparation of this edition the hand of fate has also robbed us of Mr R C Elmslie but not before he had completed the revision of those sections for which he was responsible The new contributors are Mr A J Gardham Mr V E Negus Mr L Carnac Rivett and Mr W E M Wardill The book remains a personal one and represents the views and practice of the various collaborators whose active minds and rich experience are thereby made available for the student During war years it is difficult to keep in close touch with world wide developments in the realm of surgery though the endeavour has been made But the presentation of those methods that have stood the test of time has been regarded as most important and I would remind the reader that a considerable period must always elapse before it can be said that a given modification however striking or spectacular is a real improvement rather than a mere change in technique In surgery there can be no finality but none the less methods that have proved their value are not likely to be readily displaced from current practice Let me also point out that this book deals only with the operative part of surgery and that a general knowledge of wounds and their management is assumed Many sections have been completely rewritten and all have been thoroughly revised while there is a considerable increase in the number of illustrations

In a work of this sort it is difficult to avoid a certain amount of repetition but this is sometimes deliberate to spare the reader the necessity of frequent reference to some other part of the book

As editor may I say that on the few occasions when I have found myself in disagreement with the authors I have not cared to weary the reader with dictatorial footnotes I have myself shared the heavy task of reading the proofs so that I am equally responsible for any errors that may have crept into the text My warm thanks are due to the contributors who have helped so manfully in bringing out the work It is a pleasure to thank Mr Ernest Miles once again for revising his description of the abdomino perineal operation for rectal cancer I am also obliged to Miss J M Collinson who has been responsible for the new illustrations in my own sections Finally may I express the hope that this edition will not be considered unworthy of the great Master in Surgery to whose memory it has been dedicated

G Grey Turner

PREFACE TO THE FIRST EDITION

THIS work is an attempt to present to the Profession an authoritative survey of the whole range of modern surgical operations My aim, as Editor, has been to exclude operations which have lost their usefulness (and this includes some classical operations), and among new operations to include those only which have proved their value It is possible that among the new operations left undescribed are some which are destined to attain permanency, but it is the greater wisdom ' to prove all things

MODERN OPERATIVE SURGERY makes its appeal primarily to Surgeons who desire to be informed as to the detailed technique of modern operations and at the same time it seeks to place before them the reasons for the choice of each operation, with such details of the preparation and after treatment as may conduce to a successful result Special care has been taken to deal with difficulties and dangers arising during the operation or afterwards and efforts have been made to collect results from many sources

In a composite work such as this it is difficult absolutely to avoid overlapping but this has been reduced to a minimum, nor will more variation be found in individual opinion and method than is inevitable I gladly acknowledge the readiness of my collaborators to adopt suggestions made with a view of securing as far as possible proportion of scale and uniformity of treatment

I also render grateful thanks to many colleagues and friends for assistance and individual reports and in particular to Sir Berkeley Moynihan Mr James Sherren and Mr W E Miles in this country, and to Drs W J and C H Mayo and Dr Downes in America

H W CARSON

PREFACE TO THE SECOND EDITION

THE aim and scope of this work were admirably stated in the preface to the first edition and it has been my endeavour to adhere to them

The lamented death of H W Carson left the arrangements for the present issue in active preparation The general plan of the work was to remain the same new sections on Radium and the Surgery of the Sympathetic System were to be added and new authors had been found to revise the sections for which Mr Richard Warren and the late Mr Hamilton Drummond had previously been responsible It was at that stage that I undertook the duties of Editor and I am glad to acknowledge the cordial help of the contributors of the artist and of the publishers To Mr Ernest Miles I am also grateful for again revising the account of the abdomino perineal method of excision of the rectum I am indebted to several colleagues for their help and especially to Mr James Whillis F R C S Lecturer in Anatomy in the University of Durham for most valued help and criticism and for much laborious work in proof reading

As Editor I have tried to keep in view the requirements of those who are commencing the practice of operative surgery to whom I trust the work will continue to prove a safe guide

G GREY TURNER

July 1934

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It is a commonplace to say that the days are over when operative surgery was entirely a matter of dexterity and speed in wielding the knife, but it becomes more true year by year for the art has now passed into a phase when many of the more important operations can only be described as deliberately slow and painstaking Spectacular surgery is not necessarily bad surgery, but to operate by the clock should never be made a cult nor looked upon as an ideal The measure of surgical skill must always be efficiency rather than speed *The proper operation, even if clumsily performed, is much more likely to be successful than the wrong operation, however brilliantly executed* This statement presupposes the importance of recognizing the exact indications for operation and is an illustration of the old truism that 'without forethought there can be no precision'

While it would be foolish to deny that the purely technical part of surgery has reached a high state of development it is surely more foolish to suppose that the future has no advance in store But, in spite of the position of operative surgery to day, even in the most favourable circumstances the experienced surgeon must marvel at the recuperative powers of the human body and must ever be grateful for the *vis medicatrix naturæ*

Successful surgery is founded upon accurate diagnosis —The cases in which difficulties arise both during and after operations are usually those in which it has not been possible to make a reasonably accurate diagnosis Experience soon teaches that there is wide latitude in the application of the curative measures which may be required in any particular circumstance This is very well illustrated in the treatment of tuberculosis of bones and joints for most surgeons will agree that, given suitable surroundings and the opportunity for the necessary continuity of treatment regardless of time, conservative measures will cure practically all cases At the same time if these conditions cannot be obtained, then it may be perfectly justifiable to operate An operation may be the most important factor in the management of one case whereas in another it may be merely an incident Again, it may be wise to divide the necessary operative procedures into stages This is well exemplified in the surgery of the large bowel, for it has been abundantly proved that if obstruction is first dealt with by drainage of the colon, the mortality of subsequent operation for removal of the

cause is halved. Modern diagnostic methods often indicate operations likely to be successful which formerly would have been regarded as unjustifiable. Many neurological proceedings come under this head. The refinement of the operative art has also much to do with the enlargement of the surgical field; for by careful preparatory treatment, the management of the operation itself, and skilful after treatment, contra-indications have been notably lessened. This is well illustrated by operations for hernia. In these days there are practically no contra-indications, unless indeed it be chronic cough which has defeated all treatment. With adequate preparation and special methods of anæsthesia and after care, conditions like albuminuria, diabetes and cardiac disease are no longer looked upon as necessarily contra-indications. Technical advances, such as the application of living fascial sutures, have also made it feasible to deal with types of hernia which in the past were looked upon as totally unsuited for surgical intervention.

But the mere existence of some condition which is often successfully treated by operation does not necessarily mean that this treatment should invariably be applied. This point is well illustrated by duodenal ulcer, a disease which yields to medical management in so many cases that it is unnecessary to consider operation unless (i) adequate medical measures fail to bring relief, (ii) the symptoms recur after a period of relief, (iii) the patient is unable to maintain stomach health in the environment in which he must earn a living, or (iv) there are signs of some complication like hæmorrhage or pyloric stenosis.

The Influence of age on the question of surgical intervention is sometimes great. When an operation is the only effective treatment it must be performed even at the extremes of life. Both the very young and the very old normally recover well from the inevitable trauma, but the aged are intolerant of inflammatory complications and long-drawn-out convalescence is a serious hazard. For this reason it is necessary to operate early in abdominal emergencies in old people and unwise to follow the usual practice of trying to avoid operation until it is quite inevitable.

Operability is closely bound up with the indications for interference. The object of surgery is to save life or to relieve suffering, and the magnitude of the undertaking which may be required depends on the situation, the extent and the stage of the disease. When the disease is extensive or the condition of the patient precarious, then the boldest may often be deterred from some undertaking which can only be carried out with great hazard to the patient and anxiety to those in charge. At the same time, when there is no other prospect of cure or relief the risk ought to be taken, for it is not good practice to deny the possible benefits which only an operation may offer. Those surgeons whose operability rate is the highest must needs have a heightened mortality, but it is the price that must be paid for many of the great triumphs of surgery.

There are occasions when both patient and operator may have to realize that

> " Th' abyss is worth a leap, however wide,
> When life, sweet life, is on the other side "

The probable results of surgical intervention must be assessed in relation to its limitations For instance, when the radical operation for breast cancer can be carried out before the lymph nodes are involved, the expectation of cure is probably over 80 per cent whereas when the nodes are involved the percentage falls to something like 30 and no extension of the scope of interference can bridge the gap Similarly, the behaviour of cancer of the stomach is so different from the same disease in the large bowel that the earliest and most thorough operation is only too likely to be followed by a return of gastric disease within a few years, whereas in the large bowel lifelong freedom from recurrence may be expected in very many cases Eradication of tuberculous disease of the knee with a resulting stiff joint after excision is surgically satisfactory, though the result may disappoint the patient unless he has been warned

The preparation of patients for operation is now recognized as a matter of the greatest importance The late Lord Moynihan often used to say " Surgery has been made safe for the patient, let us now make the patient safe for surgery " In this matter the worst feature is that unseemly haste which is so often forced on the surgeon—sometimes with most unfortunate results—by the limitations of hospital accommodation This is a very important matter for the community at large, but there are already indications that hospital accommodation will before long be extended until it is adequate to meet the public need

The question of where an operation should be carried out is usually easily settled, for, in the great majority of instances, it cannot be doubted that a suitably equipped hospital, whether public or private, is the proper place The remarkable development of transport in recent years has done much to solve this problem At the same time there are some emergency operations on the aged, or those particularly apprehensive, which can be more safely carried out in the patient's own surroundings To diminish the psychological shock by keeping the patient at home is sometimes just sufficient to make the balance come down on the right side Unfortunately, the younger surgeons are often at a loss when called upon to make the necessary preparations for an operation in a private house, but this ought to be part of the education of every surgeon Since most operations are now done in hospitals, either public or private, the first step in preparation is the acclimatization of the patient to the ordeal of the strange surroundings To get the best results, the surroundings should be suited to the temperament, and when that is not possible the time required to get patients accustomed to the unusual environment is well spent This is admirably illustrated by the problem of toxic goitre, for few hospitals have enough

accommodation to nurse these patients alone and the wisdom of the alternative plan of getting them accustomed to the general wards for some days before operation has been amply proved

The condition of the lungs and the cardio-vascular system must be carefully estimated It is especially important to re examine the chest between two stages of an operation as some slight disturbance following the first intervention may be aggravated by further inhalation anæsthesia No general anæsthetic should ever be given to a patient with a cold or infection in the respiratory passages Operations should preferably not be carried out during the menstrual period but if delay will be detrimental this prohibition need not be absolute Extensive breast operations however should be avoided during the congestive stage that often precedes the period for hæmorrhage may then be very troublesome or even serious

The next important point is to attend to the ordinary bodily functions and without being too drastic to see that the bowels are properly emptied and that the excretion of urine is normal Some degree of renal insufficiency is much more frequent than is often suspected Sleep and nourishment are also essential It is well to remember that special preparation is always necessary in diabetes thyroid intoxication and established jaundice The measures are detailed in the various sections

Anæmia has an important bearing on operation and should be treated beforehand The happiest augury is when the patient can repair the blood defect by natural effort assisted by nutriment and drugs but when the blood forming mechanism is at fault or there is not time to wait because of the ravages of disease then blood transfusion as a preliminary is valuable Before any operation at which considerable blood loss may be anticipated it is wise to determine the blood group in advance and to have available a suitable donor or blood from a bank Efforts have been made to raise the resistance to infection by vaccines but they cannot yet be said to have proved their efficiency Sterilization of the alimentary canal the urinary tract and—to a lesser extent—the tissues generally by medication is likely to prove of value If the stomach tube is likely to be necessary after operation it is a good plan to have it passed once or twice beforehand in order that the patient may get accustomed to what might otherwise prove an alarming ordeal

Anæsthesia becomes of ever increasing importance not so much by the extension of the scope of operations but because the net is spread so much wider and now contains so many cases which would previously have been considered unjustifiable risks Local anæsthesia is invaluable and has long since ceased to be limited to minor surgery There are very few operations which cannot be conducted under some type of local anæsthesia if the surgeon is trained not only in technique but in patience It should be part of the education of every surgeon to carry out a series of major operations under local anæsthesia

so that he may exercise those qualities, and learn especially the importance of gentle handling of both the patient and the tissues Spinal anæsthesia appears at last to be finding its proper scope As in many other problems it is the simplest plan which has weathered the storm, and drugs such as percaine, used in bulky solutions, are proving most satisfactory But it should never be used without the greatest care and without weighing up the requirements of the case Of general anæsthetics there is now a wide choice, and various methods are equally useful and interchangeable in different hands That is to say that one accustomed to use the gas oxygen ether sequence may get no more perfect result than one who is equally expert with some other combination

Anæsthesia preceded by sedative drugs has been in vogue of recent years, and has been so generally successful that premedication now plays an important part in the problem of securing the best anæsthesia Combined local anæsthesia diminishes the amount of general anæsthetic that need be used, while spinal anæsthesia as an auxiliary will sometimes provide just that sufficient relaxation which might be unobtainable under general anæsthesia alone Crile did a great deal for operative surgery when he enunciated his idea of *anoci-association*, but the creation of the atmosphere which the name implies should really begin when the patient and surgeon first come together, and be further developed as they acquire that easy confidence in each other that augurs the most successful association for both Everything that may hurt the patient, not only physically but mentally or even subconsciously, must be eliminated But the question of the anæsthesia to be used should always be settled in consultation between the surgeon and the anæsthetist, for this makes for the happiest result for both patient and operator

The general technique used in operations is now so well established that there would be little excuse for mentioning this matter unless some question of principle was involved But at the present time when, even in big centres the normal arrangements for sterilization may be suddenly interrupted by enemy action, or those without special training may be thrown into surgical work by the national emergency, occasions may arise when guidance will be of value It is ordinarily assumed that operative work can only be properly carried out by the so-called aseptic technique, in special theatres with the complete armamentarium for dry sterilization and all else that this involves In many clinics the aseptic principle is rigidly carried out, and only those actually engaged in the operation are allowed in the theatre, spectators being condemned to view the proceedings through glass screens, often a considerable distance from the operative field For the purpose of demonstrating operations this is not satisfactory , details cannot be observed and, even with the aid of loud speakers, it is not easy to explain the various steps It is perfectly true that the dry aseptic technique is efficient and much more pleasant both for the surgeon and the patient, but it

does lack a factor of safety which the use of antiseptics undoubtedly provides While using the aseptic technique I always seek the protection of an antiseptic in so far that the gloved hands are sluiced from time to time in 1/1,000 biniodide of mercury solution But whatever method is employed as a routine, all surgeons ought at least to know the essentials of an antiseptic technique especially at the present time I consider myself fortunate to have been brought up surgically in the days when the only protection from organismal invasion depended upon antiseptics used in solution From an experience of this technique over a period of several years I acquired absolute confidence in the measures then employed When the antiseptic system is thoroughly understood and carried out carefully in all its details operations can be performed with safety in any ordinary surroundings and much of my earlier work was undertaken in the small houses of the industrial workers of Tyneside Healing was satisfactory and complications from infection scarcely ever occurred

Anything that can be boiled in water can be rendered sterile, but it is also important to realize that the same end may be attained by the intelligent use of antiseptics If for instance, dry sterile towels are not available ordinary towels as they come from the laundry, can be sterilized by soaking for not less than half an hour in any of the reliable antiseptic solutions such as 1/1 000 perchloride or biniodide of mercury, 1/20 carbolic or mixtures of these There are other antiseptics such as dettol cresol and lysol, which are also effective though not quite so pleasant and sometimes more expensive But, whatever the solution it must saturate every part of the towels to be sterilized and to ensure this they must not be folded too tightly and must be squeezed out at least once while soaking When the towels are required they must be thoroughly wrung out and can then be used like dry sterile towels except that they must be laid over mackintoshes or jaconet or other thick dry towels to protect the patient's skin from the wet and the strong antiseptic In circumstances of great stress when there is a shortage of clean towels and there is no time to have them properly washed they can be rinsed thoroughly in ordinary water and can then be soaked in the strong antiseptic solution and used again with little likelihood of harm It is unpleasant and fortunately unnecessary to put on a gown soaked in this way, for an ordinary clean dry gown or apron from the laundry can be protected by pinning an antiseptic towel over its front Indeed, if due care is taken an ordinary unsterilized gown is not necessarily a source of danger provided always that what is to go into the wound is not allowed to come into contact with it With the antiseptic regimen, face masks are not essential but if considered desirable, they can be made of the plain dry gauze as supplied by the manufacturers without sterilization

Gauze swabs may also be rendered safe by immersing them in an antiseptic solution in which they can be kept and can be wrung out in boiled

water to dilute the antiseptic before touching the wound But by whatever method the swabs are prepared it is essential to have some scheme to avoid the risks of leaving them in a wound I have always relied on counting in units of five, and no distinction is made between large and small mops and swabs or strands Thus the nurse must never put out less than five mops of any sort, and any additions must always be made in fives, that basic unit is never broken The number of swabs is counted by two nurses before the operation, and written down Any further mops required during the operation are counted by the same two nurses and added to the list and at the conclusion of the operation the same pair of nurses are responsible for the final count As an additional safeguard it is a good plan to have sewn to each mop a tape which is left outside the wound and is identified by attaching an artery forceps to it If the surgeon is working in an emergency, perhaps with only one nurse, the mops must be counted and checked between them, the unit of five being strictly adhered to But there is no emergency, at least in abdominal surgery, in which this matter can be left to chance

Gloves are usually dry sterilized and this is the most convenient and economical method, but they can also be boiled For this to be effective the inside must be thoroughly wet and the gloves should be loosely wrapped in lint or cloth before boiling They can also be rendered sterile by complete immersion in an antiseptic solution for not less than half an hour, but care is necessary to ensure that the solution comes into contact with every part of the glove, both inside and out and they should be loosely wrapped in lint or cloth which soaks up the solution The young surgeon might be reminded that gloves are a comparatively modern innovation, and that, provided the hands are carefully and thoroughly washed and soaked in an antiseptic solution for several minutes and from time to time, operations can be satisfactorily carried out without them But in these circumstances the surgeon must not only exercise scrupulous care in washing and soaking the hands, but he must at all times protect them from unnecessary infection and keep the skin as smooth as possible It is sometimes forgotten that all the pioneer work, not only in abdominal surgery but in the surgery of bones and joints, was done without the rubber glove With the exercise of great care the results were excellent, but wound healing without infection was not so uniform as can be expected when gloves are used

In operations that are not emergencies the skin of the patient is usually prepared, after careful washing and shaving, by painting with iodine or one of the dyes, Bonney's blue or brilliant green being favourites I have long preferred a solution of picric acid in 1/20 watery solution of carbolic, in this preparation the picric is in a strength a little less than 2 per cent The carbolic is relied on as the antiseptic, but the picric stains the skin yellow and thus indicates the area prepared In emergency or when the skin is much soiled from garments or road or factory dirt, it should be prepared by washing with

Bipp, applied round about, is an additional factor of safety Mercurial preparations must not come in contact with this substance so that dry gauze or gauze soaked in spirit or carbolic should be employed

The general protection of the patient against infection has been attempted from time to time and the value of chemotherapy is again being explored Preparations of the sulphonamide group administered by the mouth are being used with a certain amount of encouragement These substances are also being applied to the exposed surfaces of the tissues especially in injury In deliberate surgical interventions this step can seldom be indicated but if considered necessary, it can be employed without interfering with healing

Thoroughness in surgery is of the utmost importance, for any lack of attention to detail can seldom be made good by subsequent management Of most operations it can be truly said that the patient's best chance lies in the first intervention This can be well emphasized by reference to the radical cure of inguinal hernia, for in this operation all the steps may be carried out according to classical description and yet fail for lack of thoroughness in execution Often, too little care is taken to isolate the parts about the neck of the sac sufficiently thoroughly and the ligature is applied while that structure is relaxed and limp For a good radical cure the sac must be ligatured off at the highest possible point, and in order to do this thoroughly not only must the external oblique be divided to well above the internal ring but the sac, having been separated from the structures of the cord, must be steadily and firmly pulled upon while the parts about its neck are isolated by gauze stripping It is essential that the sac should then be kept taut while the ligature is applied to the highest point If this step has been properly carried out then after the sac is cut away the ligatured stump should retract into the extra-peritoneal tissues, well out of sight When recurrence follows an operation for oblique inguinal hernia it often occurs just near the pubes and really represents the development of a new direct hernia rather than the re forming of an oblique inguinal sac This is often due to incomplete closure of the extreme inner end of the canal at the original operation To guard against such a mishap the sutures must be inserted right up to the inner end of the canal and, indeed, the terminal stitch should be passed between the conjoined tendon and the attachment of Poupart's ligament to the periosteum of the pubes If these points do not receive careful attention the result is apt to fall short of complete success

In operations for malignant disease thoroughness is especially important and the surgeon should not undertake this treatment unless he feels convinced that it is the best possible method for that particular case The aim which must always be kept in mind is *the removal of the whole of the affected part, together with a wide area of healthy tissue and the path of probable malignant invasion* To define the extent of the "wide area" may be difficult and it is not always possible to take

away the whole "path of probable invasion," but this conception of the aims of the operation is a most helpful guide Whenever possible, such an operation should be carried out *en bloc* The treatment of pilonidal sinus has often been a reproach to surgery entirely on account of lack of thoroughness in its operative removal It must first be realized that, in order to be sure that none of the secreting epithelium of the wall of the sinus is left behind, it is necessary to remove a considerable amount of the tissues all round This means taking away an elliptical area of skin and subcutaneous tissue surrounding the sinus To ensure that this removal is sufficiently thorough on the deep aspect it is necessary to remove the tissues down to the periosteum of the sacrum As a result of this complete ablation a considerable crater is formed Sometimes the edges can be brought comfortably together by sutures, taking a wide grasp of the skin and subcutaneous tissue, but if there is too much tension the wound must be left open, loosely packed with gauze and allowed to heal by granulation Complete cicatrization takes place in a few weeks, but the reward of this thorough treatment is permanent cure

But thoroughness in carrying out operations will often be robbed of success unless the same effort at completeness is applied to diagnosis, preparation and after care

In the actual conduct of operations the present tendency is to do with fewer assistants, to pay greater regard to illumination, to use the tissues gently and kindly and to take scrupulous care that blood loss is reduced to a minimum The care of the patient on the operating-table is very important, and it is essential not only that he should be kept warm, but that he should not be over-heated or covered with mackintoshes, which cause profuse perspiration

In most major operations the blood pressure should be recorded throughout A sudden fall or a gradual deterioration to the neighbourhood of 100 systolic are both indications for intravenous saline, which can be followed directly with blood, if necessary Where some degree of shock is expected it is a good plan to have the intravenous needle inserted and the apparatus connected up at the outset of the operation Caution must be exercised in changing the position of patients under anæsthesia, especially if any degree of shock has developed. Any such change should be made slowly and gently and a little time should be allowed for natural adjustment before the operation is resumed In operations on the brain or any severe operation it is a wise precaution to remember the physiological principle of the "summation of impulses" and to give the patient a rest by interrupting the operation for five or ten minutes This may be done more than once in any very long intervention

Some surgeons prefer only daylight, while others prefer wholly artificial light, and between the two there are many gradations This is not a matter for dogmatism

The after-care of operation cases is most important but the special

management which may be necessary after the individual operations is considered in the various sections, and only general observations are made here Just as the young surgeon should carry out some major operations under local anæsthesia in order to learn gentleness in manipulation, so he should consider it a bounden duty to care for his patients after operation, in order to acquire that intuition which tells him when progress is satisfactory or otherwise The general appearance of the patient often furnishes most important information, and the surgeon should cultivate the art of observation in order to learn to appreciate the small things which may prove such valuable indications of general progress Operations properly indicated, adequately prepared for, and carefully performed at the proper time are not usually attended by much anxiety during convalescence, but conditions vary, and the surgeon must be able to deal with discomforts as they arise In the immediate after-care it is well to remember that the pain of returning sensibility will have to be treated by drugs, of which morphia is still by far the most generally satisfactory and useful The pain that persists longer than twelve hours, or that recurs after relief during that period, is probably due to some cause that can be determined and removed It may be a tight bandage, a distended bladder, or flatulent stomach or intestine, and each of these require adjustment rather than disguise by further narcotic medication Both in preparation and after-treatment the stomach tube is invaluable, and continuous drainage by Ryle's tube is proving very useful The desire to keep up the fluid intake by intravenous or even rectal administration may be overdone, and the sooner the patient can receive a satisfying amount of liquid by the mouth, the better

Cough may be protective and should not be hastily stifled by drugs In the early postoperative stages an accumulation of more or less tenacious mucus or muco purulent sputum sets up the cough reflex As pain, often severe accompanies the effort of coughing, the patient endeavours to prevent it and in consequence the bronchial tree tends to become loaded with secretion , and complications from infection, such as bronchitis or broncho pneumonia, or from mechanical blockage, like lung collapse, are apt to follow The proper treatment is to assist the patient to empty the bronchi by supporting the area of the wound by firm pressure with the flat of the hand, while the patient is encouraged to cough , if this is done every few hours it is most helpful Sometimes drugs which stimulate coughing and soften the bronchial secretions may also be required

It is because early vomiting and coughing do put a strain on abdominal wounds that a firm bandage, sometimes with additional elastic support, may be so helpful Sometimes such a bandage, applied under anæsthesia, may prove too tight and may interfere with the free movement of the lower chest and abdomen It should be the rule to examine the bandage each morning and to adjust it as required At the expiry of a few days such a bandage may usually be discarded,

the dressing being fixed with strapping or even dispensed with altogether

Vomiting that persists after the first few hours should prompt enquiry as to its cause and of course it is of the greatest importance to examine the vomited material from time to time When intestinal peristalsis recommences vomiting will usually cease though there are some patients in whom it persists for two or three days If not very troublesome no treatment other than absolute quiet is necessary the patient should not be disturbed If persistent and distressing copious draughts of very hot water or half a glassful of water with a teaspoonful of bicarbonate of soda or stomach washing will usually bring relief

Intestinal torpidity renal insufficiency or pancreatic insufficiency are all factors that may have a bearing on continued vomiting Intestinal movements may be encouraged by rectal enemata subcutaneous injections of strychnine pituitary extract small doses of calomel warmth inhalation of nearly pure oxygen the use of stimulants or induced sleep When it can be tolerated nutriment by the mouth especially if desired by the patient does more than anything else to encourage intestinal movement In those patients who remain sick an intravenous glucose saline drink may do a great deal of good

Abdominal distension which unduly persists strongly suggests intra abdominal infection Drastic purgatives should be avoided but if the tongue is very dirty and the breath foul a full dose (one ounce) of castor oil is often most effective Should the patient be nauseated by the oil or dislike it too much then two or three grains of calomel in divided doses (half a grain every half hour) may be effective but its action may have to be assisted by a saline draught or an enema In most cases a glycerine enema will often start bowel movement It may be a great help to allow elderly or nervous irritable subjects to get up on to a commode and this does far less harm than harassing them with repeated purgatives or enemata

Retention of urine is not frequent in these days In most cases it can be met by an easy rather airily-expressed confidence on the part of those in charge The talk or threat of catheterization often makes matters worse The privacy of a screen around the bed change of position pressure over the pubes or getting up on the knees or even getting out of bed are all better expedients than the hasty use of the catheter Doryl or its substitute is often effective The need of care in catherization cannot be overstressed

Sleeplessness is not to be treated only by drugs for a careful consideration of all the circumstances may give a clue to its management Hunger is not an uncommon cause The more the conditions in which the patient usually sleeps can be imitated the more successful will its management become Anxiety about the operation is often a factor and a few words of encouragement may work wonders But full explanations should be reserved for later days Nothing can do more good than to be able to say all was successful or everything went

well," but to have to say "there is no need to worry, you will be told all about it in a day or two" will often produce the desired calm Many patients suffer much anxiety because they are unaware that some pain and distress are to be expected, and once they are assured that it is quite natural they endure with patience After any serious operation the patient should be encouraged to sleep at any time, it is wonderful how refreshing even a short snatch may prove Besides, sleep is a habit and nature's promptings should be followed There is no greater folly than to suppose that by fighting sleep throughout the day its comforting embraces will follow naturally when night arrives If some medicine is necessary it is a golden rule never to use opiates except for the relief of pain and the simplest drugs that will suffice are always the best

There has been much discussion on the question of **when to get patients out of bed** after operations Every operation is an ordeal and the severity of that ordeal does not depend only upon the particular operation but on the reaction of the particular patient Most patients really require a rest of two or three weeks in bed after any operation of magnitude, and it is usually appreciated If the patient is not doing well it may be wise to get him out of bed as a therapeutic measure during the early days, but this is seldom indicated With some surgeons early rising for their patients—within two or three days of operation—is a cult, and deliberately carried out as a means of hastening convalescence This practice has never become popular in this country, but the fact that patients who do get up early often make very good recoveries at least teaches us that there need be no hesitation in adopting early rising if it is likely to be an advantage in any particular case

While the immediate after care demands close attention, the **remote after-care**, though in a different category, is none the less important After gastro intestinal operations, for instance, the care of the teeth, the regulation of the diet and of the habits of life are all matters of moment and may have great bearing on the success of the operation For malignant disease most surgeons are conscious of the difficulty of deciding whether measures designed to guard against recurrence, such as postoperative irradiation, are really helpful, or whether they may not do harm by focusing the attention of the patient on the unfortunate possibilities Some plan of prophylaxis is very desirable, but it may well come through some form of hæmotherapy rather than the local means at present in vogue

The long continued observation of patients after operations is a valuable means of assessing value Some sort of follow up scheme is an essential part of any properly organized surgical service

The causes of mortality after operation deserve very careful consideration The most disquieting are the sudden deaths, some of which are not to be explained even after the most careful post-mortem scrutiny Pulmonary embolism is still to be feared as a visitation, and

it is questionable if the dramatic results which have on rare occasions attended its surgical treatment will do much to diminish its general mortality Evidence is accumulating which rather goes to show that a less strict postoperative regime is probably helpful in prophylaxis

It must be admitted that pulmonary complications occur in about 10 per cent of all operation cases and this figure is much higher for upper abdominal operations These complications account for a considerable number of deaths and their prevention and management is therefore especially important

The effect of chronic infection on the heart-muscle is very important, and many so-called cardiac failures are due to this cause, some sort of infection having been in existence for a long time, producing its deleterious effect unsuspected and unchecked

Nothing has done more to reduce surgical mortality than careful and timely preparation but this must be supplemented by the most rigid attention to the details of operative technique and constant vigilance in after-care

The general mortality rate of the various operations is dealt with in the sections It may here be remarked that the publication of extraordinarily low figures in works on surgery is likely to do harm rather than to prove a stimulus to further effort Such figures sometimes strain veracity to the breaking point and may even bring ridicule on surgery All deaths which occur in hospital after operation must be counted as operative deaths, irrespective of the cause The acid test is the outlook of the relatives, who not unfairly reduce the matter to the simplest terms when they comment that " after the operation the patient died

Operations in the presence of some other disease—Surgical interference may be necessary in **diabetes** During recent years the use of insulin and closer attention to the diabetic state has much improved the outlook Even when the operation is an emergency, the appropriate measures for the control of the diabetes must be brought into use immediately Though the most important matters are diet and insulin, the need of free movement of the bowel and a plentiful supply of fluids must not be overlooked The selection of the anæsthetic is most important Chloroform should never be used and ether very sparingly, whenever it will fulfil the indications spinal anæsthesia should be selected local anæsthesia should be avoided if there is infection When the operation is one of election the indications must be closely scrutinized for diabetics—especially when young—are poor subjects, and operations should never be undertaken until the diabetic state has been brought under complete control The actual management of the diabetes should be in the hands of someone thoroughly accustomed to treating the disease The general plan is to allow the accustomed diet and usual dose of insulin up to the day of operation On that day any nourishment is limited to carbohydrate and an hour before operation 30 grams of glucose are given by the mouth and 15

units of insulin by injection It is in the early post-operative period that the condition must be most closely watched There are certain complications in diabetics that require surgical interference and it must be accepted that septic foci should be eradicated or drained as soon as possible In obvious gangrene of an extremity, prompt amputation will usually be called for When the process is limited to the toes, there is no sign of spreading, the vessels are in good condition and the diabetes can readily be controlled, then separation of the dead toes may occur spontaneously and the parts may heal Gangrene commencing in the sole of the foot or about the heel seldom does well and this localization is in itself almost an indication for amputation

Heart disease —Using the term in its widest sense this is not necessarily a contra indication, but it adds a decided risk to operation Those forms which are readily diagnosed and which can be compensated by appropriate management cause less anxiety than coronary disease, where there is so often degenerative change in the heart muscle Even in the latter condition really necessary operations may be undertaken, especially since the relief afforded often benefits the cardiac mischief Conditions which threaten life, such as strangulated hernia, perforation of a viscus, or acute appendicitis, must be dealt with by the simplest possible measures Local anæsthesia, combined if necessary with a minimum of gas and oxygen, will suffice for most such operations Conditions that are less urgent, but in which operation may be highly desirable, must wait until the cardiac condition has been properly assessed and the patient prepared for the unwonted stress There are also circumstances in which the cardiac condition is worsened by some disability which can be dealt with by operation Chronic septic absorption from the biliary tract is a good illustration, and there are many cardiac disturbances which are greatly improved by an operation on the gall bladder Renal insufficiency associated with enlarged prostate furnishes another example, for in these cases bladder drainage often proves beneficial to the heart

High blood-pressure is often temporarily improved by some necessary operation, especially if it is accompanied by a reasonable amount of blood loss The treatment of a septic focus, or of renal embarrassment by bladder drainage in cases of enlarged prostate, often does much good But operations that are entirely optional should be avoided in marked hypertension unless there is likely to be some great compensating advantage

Pulmonary tuberculosis *which is not itself the object of surgical intervention* —Acute emergencies must be dealt with by life-saving interventions and it is then largely a question of selecting the form of anæsthesia which is least likely to be harmful to the pulmonary condition Sometimes duodenal ulcer or pyloric stenosis may seriously interfere with that proper nutrition which is so necessary to combat phthisis In these circumstances gastro-enterostomy may be carried out with great advantage Intestinal obstructive symptoms also

demand surgical intervention, and quite often a short-circuiting or even intestinal resection may be of immense benefit But the surgeon should be very suspicious of diarrhœa as a symptom, for it nearly always means tuberculous enteritis and is of grave prognosis. In all these interventions local or spinal anæsthesia should be employed It is perfectly true that many patients with quiescent tuberculous lesions tolerate general anæsthesia quite well, but should a lesion be lighted up the surgeon will feel responsible, and in any event convalescence is apt to be greatly prolonged

Among other pulmonary conditions bronchiectasis is important When the condition is in a dry stage a general anæsthetic may be well tolerated, but in the active phase with copious sputum only local anæsthesia is permissible Whenever possible, interference should be postponed until the bronchi can be drained by postural and other measures Patients who suffer from asthma often seem to be temporarily improved by general anæsthesia, but this fortunate result cannot be relied upon so that local anæsthesia should be employed whenever it will suffice In chronic respiratory diseases, operations that can be safely postponed are better dealt with during the summer months or at least at such a time as the patient recognizes from previous experience that the chest condition is likely to be least troublesome

Hæmophilia—Only really urgent life-saving operations are permissible and they should be carried out immediately after blood transfusion The smallest incisions and the fewest needle punctures that will suffice should be employed, and punctilious care must be taken to secure all bleeding points Among styptics, snake venom (Russell s viper) of a dilution of 1/10,000 used locally, is said to be most effective and free from harmful effects Turpentine, being more readily obtainable and most effective if properly used should not be forgotten

Insane patients usually become quite docile in acute surgical emergency and there is no reason why necessary life-saving operations should not be carried out successfully In an extensive experience I do not recall a single case in which there were unusual difficulties in after-care Apart from emergencies conditions threatening life or causing pain or grave disability should be dealt with by operation No ethical considerations should deter the surgeon from giving such relief as his art can afford The probable progress of the mental disease will naturally be taken into consideration, but that is a matter for the alienist rather than the surgeon

Pregnancy in abdominal emergencies is an indication for early intervention rather than delay Appendicitis, treated before peritoneal complications arise or become serious, does very well indeed and, even if drainage is necessary, pregnancy is seldom interrupted Operations of election that can be postponed should be allowed to wait until after delivery Malignant disease of the breast runs a very rapid course during pregnancy and its presence raises very serious questions Unless there are very special reasons against it, the pregnancy should

usually be terminated and the complete radical breast operation carried out

War surgery —The scope of this work as a guide to the operations of surgery does not embrace the general management of gunshot wounds, but in many of the sections there are references to matters of importance in military practice The following notes may provide some guidance to the primary treatment of war wounds *It is essential to recognize that those general principles which afford guidance in civilian surgery also govern the management of injuries met with in warfare, and the more closely such principles can be observed the better, the results* But whatever our aims and our plans for the treatment of those wounded in battle the first and often the greatest problem is the question of transportation, so that casualties may be brought to the surgeons working in suitably equipped hospitals within a reasonable time In the more or less static warfare which prevailed during a great part of the campaigns of 1914–18 this was difficult enough, but in certain areas it was eventually possible to arrange for treatment in the casualty clearing stations in from 6 to 10 hours In the intense mobile warfare which characterizes the present world conflict the difficulties have been extreme and there has often been great delay, extending to 24 hours or longer When the surgeon can be taken to the wounded man the prospect would appear better, but this has usually only been possible in such circumstances that little in the way of surgical intervention could be carried out

Until such time as hospital treatment is possible the main indications are to arrest hæmorrhage, to treat shock and to prevent infection, but the best means of attaining the latter objective as a first-aid measure is still in much doubt There are many different varieties of war wounds, from the comparatively simple through-and through bullet-wound to the very severe injuries produced by shell fragments The injuries are often multiple, and several different types of wound may be found in the same patient The local injury may extend far beyond the original site, and in some cases there is a special tendency to disruption of the surrounding parts This particularly affects the muscles, which are found greyish, almost avascular and without the power to contract on mechanical stimulation The condition is sometimes spoken of as "muscle stupor" Such tissue provides an excellent culture medium for anærobic organisms Another feature of these severe wounds is the tendency to reactionary œdema, which causes much swelling, with tension beneath the deep fascia and consequent interference with circulation and with drainage Though so many of these wounds are contaminated with organisms at the outset, they are not actively infected until the organisms begin to multiply in the tissues No stated time can be given at which this takes place, but for the most part it is not likely to be established until from 6 to 12 hours after the wound There are also types of injury, especially to the viscera, which are due to compression or blast from high explosives The location

of the wound may bear little relation to the injury inflicted as for instance wounds of the buttocks which are notoriously dangerous for they are so often complicated by serious abdominal lesions

Apart from the type of wound the general condition of the patient must be taken into consideration for the effects of blood loss and shock are often important With the exception of clean through and through or traversing bullet wounds *war wounds in general require such a complete toilet as to amount to a surgical operation* and it is on the care and thoroughness with which this can be carried out that the ultimate result largely depends The main object of the intervention is to anticipate sepsis by excising all torn and devitalized tissues and to expose and cleanse every part of the depths of the wound But to be successful this intervention must be undertaken before organisms have begun to multiply in the tissues To carry out this wound toilet properly the part must be anæsthetized and in British practice inhalation anæsthesia is nearly always employed With the help of all the arrangements for a major operation the wound must be enlarged so that every part of its depths can be explored This is combined with the excision of the contused and lacerated tissue and to that extent it is a wound excision but it is not necessary to do a formal *en bloc* excision in every case or to remove any great amount of the tissue surrounding the wound While it may be expedient completely to excise the whole of the damaged tissues in the smaller wounds to attempt such a complete excision in the larger wounds is likely to lead to an unnecessary and harmful amount of additional traumatism But in these larger wounds bruised and lacerated skin torn and frayed fascia separated muscle or muscle without life must all be removed with scalpel and scissors until healthy looking and freely bleeding tissues are exposed For the skin a margin of about a quarter of an inch around the damaged edges will suffice Blood clot debris and easily accessible foreign bodies should be removed and bleeding vessels secured It is a great help in the examination of the depths of the wound and an incentive to healing to have all bleeding arrested and the aim must always be to do this by ligature applied to the bleeding site For these purposes the depths of the wound must be inspected and retractors are invaluable The thorough exploration provides an opportunity of examining the extent of the damage to structures like muscles tendons arteries nerves and bones If the wound is dealt with about six hours after infliction immediate repair of the soft parts may be attempted otherwise it is usually considered better to defer nerve and tendon suture for secondary operations to be carried out after the wound has soundly healed The thorough exploration and exposure of the depths of the wound also provide an opportunity for treating its surfaces with some antibacterial substance the most popular at present being drugs of the sulphanilamide group As yet there is no general agreement on their utility but it can be emphatically stated that the neglect of proper wound toilet cannot be compensated for by even the most liberal use of sulphanilamide

After the toilet of the wound has been adequately carried out, it is the present practice to leave it entirely open with or without light gauze packing. Firm packing is sometimes used for the arrest of hæmorrhage, but this should be avoided whenever possible as it interferes with the circulation and with drainage, causes pain and usually requires an anæsthetic for its removal. Drainage is probably most efficient when the gauze is thickly smeared with vaseline, but when a pack is used to arrest hæmorrhage it should either be plain dry gauze or gauze dusted with sulphanilamide powder. Vaseline packs are safely extruded during healing. At the moment, primary wound suture is out of favour, but there is little objection to secondary suture when it is likely to facilitate healing, but in practice it is seldom necessary. If there are already signs of infection, such as are likely to be in evidence after 18 to 24 hours, it is too late for a complete wound toilet and all that can then be done is to open up the wound, so that drainage may be unimpeded, and to remove loose foreign bodies and débris. Free incision of the skin and the restraining deep fascia is most important and counter incisions may be valuable. Any further interference at this stage is likely to do more harm than good.

Many workers, notably Trueta, have advocated *immobilization as an adjunct to wound healing*. The complete rest deters the absorption of organisms and toxins and also encourages healing. To secure immobilization, the limb is commonly encased in plaster of Paris, which is applied over the dressings or direct to the skin, the latter being smeared with vaseline to prevent the plaster adhering to the hairs; windows should be avoided. If all goes well, the plaster may be left in position for from 2 to 6 weeks, when the wounds are usually found to be granulating satisfactorily. During most of this period the patient should be kept at rest with the affected limb horizontal. Healing often occurs with surprising speed, but there can be no absolute certainty that this will follow without infection, and for that reason the wounded should be under skilled supervision for at least four days after application of the plaster. Inflammatory swelling beneath the unyielding plaster may lead to the most serious consequences, such as gangrene, which only prompt removal of the plaster will arrest or mitigate. This plaster method has been very generally adopted and, though in slighter wounds it is not essential, in severe deep wounds there can be no doubt of the great benefit of immobilization by this means.

In fractures or wounds of bone it is necessary to take care that the bones are in proper alignment. If the site is explored, loose bone fragments should not be hastily removed but should be moulded into position. Even if such fragments subsequently necrose, in the meantime they furnish the best stimulus to repair and bone formation. Immobilization must be secured as soon as possible, as the best means of reducing shock, and in the lower extremity it must be made adequate by including the joints above and below the site. Plaster of Paris is convenient and satisfactorily excludes sepsis, but the important

principle is the rest to the parts provided by immobilization however this is secured The Thomas s splint or even wooden splints if intelligently applied may be quite satisfactory Plaster slabs fashioned for two surfaces of a limb and kept in position by a few turns of plaster bandage have the advantage that they can very readily be removed using only ordinary scissors To get the best use from plaster the technique of its application must be thoroughly understood Fixation by plates or bone grafting is not employed in recent war wounds

When *amputation* is called for the principles observed in civil life can usually be employed and ablation of a limb by the guillotine method is seldom required Even in the worst case it is usually possible to make short skin flaps and these may be left without sutures or loosely drawn together over gauze so that when risk of infection has disappeared secondary suture may be carried out Recent amputation cases travel badly and it has been found that the support of a plaster cap over the stump is helpful

Wounds involving the body cavities usually require operation and a nice judgment must decide those that have the best chance if left alone—as for instance in some of the cases where it is probable that the liver is the only organ involved Where there is great *laceration of the soft parts about the face* neck or the flexures crippling deformity is frequently a sequel calling for much ingenuity in plastic repair Whenever circumstances permit great care should be taken in the primary treatment of these injuries with a view to the prevention of deformity but when there has been great loss of tissue it is a mistake to attempt plastic repair as a first intervention The surgeon must endeavour to prevent loss of tissue from necrosis often the result of tension following ill considered attempts to draw widely separated edges together and also to prevent unnecessary retraction of wound edges Above all else sepsis must be avoided

On general principles *foreign bodies should be removed* whenever wounds are explored and the foreign bodies are easily accessible But this rule must be applied with discretion for very small foreign bodies deeply imbedded in muscular parts or multiple small foreign bodies are best left alone It does not follow that they will prove harmless but they are better left undisturbed unless symptoms arise There must also be reservations about missiles in the brain the lungs or the abdominal viscera all of which require special consideration In any case missiles that cannot be seen in wounds or felt in the soft parts must be carefully localized before attempts to remove them are undertaken

The principle of short circuiting can often be usefully applied in military surgery colostomy for wounds of the colon or rectum cystostomy when the bladder or urethra are injured or gastrostomy for severe wounds about the floor of the mouth or pharynx

CHAPTER I

ANÆSTHETICS

By J. BLOMFIELD, O.B.E.

Physiological action of anæsthetics.—Experiment has shown that chloroform enters the blood stream from the alveoli of the lung by a process which does not depend merely on the laws of diffusion of gases in accordance with their tension. It enters into a close physico chemical association with the elements of the blood, from which it is separated with difficulty. It is the red corpuscles that mainly hold the chloroform. The work of Buckmaster and Gardner shows that the blood plasma holds no chloroform unless this is being inhaled in excessive concentration. The red corpuscles, by holding the chloroform, undergo a reduction in their oxygen carrying capacity, so that there is less oxyhæmoglobin during anæsthesia, and the lowering of oxygenation may reach 40 per cent. There is also less carbon dioxide formation owing to the general lowering of metabolism during narcosis. Chloroform is not split up in the body according to the researches of British physiologists who have repeated and confuted the experiments of Nicloux. It is believed that the essential change which anæsthetics produce on reaching the cellular elements of the body is an alteration in the permeability and the electro polarity of the limiting membrane of the plasma. The elements of the tissues thus assume a state of reversible insensibility which constitutes anæsthesia (Lille). These physiological facts are true, in the main of the other inhalation anæsthetics as well as of chloroform.

Assumption and elimination of inhaled anæsthetics go on simultaneously at the alveolar surfaces. Within the first two minutes the blood rapidly takes up the anæsthetic offered to it, until an equilibrium is reached between the vapour in the alveoli and that combined in the blood. Then absorption and elimination go on equally until the end of administration. The initial rate of elimination is never equal to that of assumption, and it takes hours for chloroform to leave the body. It is reckoned that of the amount of chloroform inhaled, half is at once eliminated by the lungs.

After death, all odour of chloroform soon disappears, and it is stated that after half an hour chloroform can no longer be extracted from the tissues (Buxton). Chloroform in common probably, with other anæsthetics, has an affinity for the lipoid elements of protoplasm. As these are present in large proportion in the nerve-tissues of the body, this is held to explain the elective affinity which anæsthetics

bave for the nervous system A greater proportion of chloroform can be recovered from the nervous than from the other tissues of the body after death and the central nervous system holds the anæsthetic more than the peripheral

With the possible exception of nitrous oxide gas ethylene and cyclopropane general anæsthetics are capable of injuring the parenchymatous tissues especially the liver and kidneys This toxic effect is produced by chloroform more readily and more severely than by other anæsthetics Fatty degeneration of liver heart spleen kidneys and voluntary muscles has followed repeated administration At the same time it has recently been shown that ether invariably induces cholæmia although this never reaches the point of jaundice Experimentally fatty degeneration in liver and kidney has repeatedly been produced and may follow repeated administration even of normal strengths of chloroform vapour Extreme fatty degeneration is familiar clinically in association with postanæsthetic toxæmia Chloroform destroys red blood-cells Nitrous-oxide gas leads to raised blood pressure Other anæsthetics cause a fall after a preliminary rise and also lower the body temperature Respiration is usually quickened but long continued or very strong anæsthetics generally paralyse the respiratory centre Chloroform is peculiar in that fibrillation of the heart muscle is apt to be set up during incomplete narcosis

SELECTION OF ANÆSTHETIC

The successful administration of an anæsthetic depends largely on the selection of the agent and the method In other articles the writers point out the anæsthetic which they prefer for the operations with which they are dealing In any special operation or particularly difficult patient it is a great advantage if surgeon and anæsthetist consult beforehand

The condition of the patient—Even among those in ordinary health there is a difference in the way in which people of different physique and temperament react to anæsthetics The more muscular and full blooded a patient the less easily does he enter narcosis Short thick necks and narrow air passages easily lead to spasm and congestion of tongue fauces and all the parts about the upper air passages Patients with these anatomical peculiarities are bad subjects for nitrous oxide anæsthesia nor are they quietly put under ether with any closed apparatus On the other hand ethyl chloride as a preliminary to closed ether is very satisfactory with such people Obstruction in the upper air passages is best prevented by putting a small prop between the teeth at the very beginning During anæsthesia an artificial airway obviates the nuisance of spasm or congestion in the upper air passages if even this is insufficient the difficulty can be completely overcome by passing an endotracheal tube through the nose or the mouth

Ethyl chloride with closed ether is also excellent for *alcoholics*, who are resistant to all anæsthetics Not only are they apt to be excited and to take a long time to enter narcosis, but when apparently in full anæsthesia they display an inordinate reflex activity They may move during operation even when they seem to be drenched with the anæsthetic and show every symptom of deep narcosis Highly nervous persons also seem to retain, even after consciousness is abolished, some form of unusual nervous excitability Dudley Buxton has suggested that the subconscious mentality is active after gross consciousness is abolished The ' awareness " in the lower centres is apparently still awake in these people For them, preliminary injections of omnopon and scopolamine are invaluable Indeed, these drugs may with advantage be used to induce a drowsiness, amounting almost to insensibility, before inhalation begins Doses of omnopon, gr $\frac{1}{3}$, with scopolamine, gr $\frac{1}{150}$, an hour and a half before, and scopolamine again, gr $\frac{1}{150}$, half an hour before operation, are usually adequate It is true that after such injections the breathing is slower and, consequently, the anæsthetic more slowly inhaled, but the extra time is more than compensated by the absence of all physical disturbance Deep chloroform narcosis after such injections is apt dangerously to depress the respiratory centre, and must be avoided

The *infant* needs special consideration A disproportionate number of anæsthetic deaths occur in the very young One reason for this is that the anæsthetist often fails to realize how deep a narcosis is needed to produce absolute immobility The ceaseless activity of the waking infant is represented during narcosis by an excitability of the lower centres that is shown by reflex movements these persist after a degree of narcosis has been reached which, in the normal adult would involve absolute stillness Consequently, to go beyond this and attempt absolute stillness is often to run grave risk In circumcision, for instance, the anæsthetist should be content with complete unconsciousness, and for absolute immobility should rely on having the thighs firmly grasped by nurse or assistant at the moment of the cut In the operation for cleft palate a deep narcosis is required, and stillness cannot be secured by any mechanical means Colonic oil ether is very useful for these patients If it does not provide all the narcosis needed, it does at any rate put the patient into a state in which but little additional inhalation of warmed chloroform or ether vapour easily maintains the desired anæsthesia The same result can be reached by rectal paraldehyde or avertin (*see* p 41)

In all *feeble subjects*, whether their weakness is natural or acquired by illness it is an advantage to add oxygen to any anæsthetic employed When anæmia is present, this is especially necessary The oxygen-carrying power of the blood is already reduced, and anæsthesia still further lessens it, and *the red corpuscles need all the oxygen they* can possibly take up and carry

Persons suffering from *injury or disease of the brain* generally require only a slight narcosis When there is drowsiness, and still more when

coma is already present no attempt should be made to secure anæsthesia before the incision When this is made it often rouses the patient so much that administration is indicated Chloroform and oxygen given from a regulating apparatus is generally the most appropriate anæsthetic but oxygen passed over ether answers admirably when the general condition is serious An endotracheal method is essential when a very flexed position of the head is required for occipital operations Either nitrous oxide or ether may be given in this way

When there is *dyspnœa* due to obstruction in the upper air passages or larynx anæsthesia is fraught with especial danger The extraordinary muscles of respiration which in these circumstances are essential for breathing are thrown out of use by narcosis and automatic respiration may be impossible When local anæsthesia suffices as for tracheotomy it is the method of choice Otherwise, chloroform in weak vapour accompanied by oxygen is recommended Colonic oil ether or avertin may also suit well and have been successfully given for many *goitre operations* where dyspnœa was present *Cellulitis of the neck* (Ludwig s angina) is often accompanied by some œdema of the larynx there may be no obvious dyspnœa and yet the patients are readily asphyxiated if wrongly treated In particular they are almost unique in their liability to special danger if given nitrous oxide a rapid and fatal engorgement of the upper air passages has on several occasions occurred under this anæsthetic The operation needed is generally very short often merely incision and so nitrous oxide is naturally suggested but the safest plan is a light narcosis secured by C E mixture from an open mask the patient lying on the side with the mouth propped open

Those suffering from *exophthalmic goitre* must be treated with special regard to the psychic element which plays so prominent a part in their malady Everything must be done to allay fear and apprehension Crile s method of stealing the thyroid is valuable This process involves daily rehearsal of whatever form of anæsthesia is going to be employed for the operation but without using any anæsthetic Thus the patient is given saline per rectum daily at the hour which will be chosen for the administration of a rectal anæsthetic whether it is to be avertin ether or paraldehyde She is also given a hypodermic injection of water On the operation day the hypodermic injection contains omnopon with scopolamine and the rectal injection contains the chosen anæsthetic In this way she is anæsthetized and operated on without ever knowing that anything unusual was to happen Recently the barbiturate compounds pentothal and nembutal given either by the mouth or into a vein have been successfully employed to induce unconsciousness before the patient is taken from her bed Many anæsthetists prefer a light anæsthesia with open ether or tracheal insufflation relying on hypodermic injection and their own general attitude to procure the necessary mental calm An accurate estimation of the myocardial degeneration and of the tracheal deformity

produced by the goitre must be obtained beforehand X-ray and electro-cardiographic examinations are needed for this purpose

When abnormal breathing is due to *disease within the chest*, the problem is different Here the first necessity is to avoid giving anything which may aggravate the disease, and the second, by care as to posture, to minimize immediate risk Warm chloroform vapour with oxygen is generally the most suitable agent if there is great difficulty in breathing The position must be that in which the patient breathes most easily when awake In operating for *empyema*, the affected side must be kept undermost, to avoid the danger of flooding the sound lung if the empyema bursts into the bronchus I have seen this accident, with a patient lying on the sound side, and death followed almost immediately Nitrous oxide and oxygen often suffices for operations on patients with intrapulmonary disorders and should always be chosen if possible It can be given through a face mask except when both pleural cavities are likely to be laid open or traction made in the mediastinum Then the endotracheal method must be employed

Major operations for conditions within the chest which have increased both in frequency and in extent of recent years, require an anæsthetist expert in that particular work Intubation of the trachea is often needed For lobectomy this needs to be of a special kind, a catheter being passed into the bronchus of the affected side and left *in situ*, suction being applied when necessary Another method (Waters) entails the passing of a tube into the bronchus of the sound side and inflating a rubber balloon at the bifurcation of the treachea Magill has devised a tracheascope and anæsthetic tube which facilitates the necessary intubation for lobectomy * The anæsthetics of choice for most major thoracic operations are either gas and oxygen assisted if necessary by divinyl ether or chloroform, or else cyclopropane The apparatus must be capable of giving positive pressure *Spinal analgesia* has been used with excellent results for lower thoracoplasty and for lobectomy A preliminary sedative is required

Proper position is all important in patients with *intestinal obstruction* who have been vomiting for several hours or days The thin, dark vomit, mainly consisting of altered blood pigments, oozes from the alimentary mucous membrane and is regurgitated from the mouth almost without effort Its escape may thus be unnoticed during anæsthesia until the pharynx is swamped and the insensitive larynx invaded, with dire consequences Washing out the stomach beforehand gives so short a relief that it is not worth doing Before administration, the patient must be placed on the table in such a position that invasion of the larynx by fluids passing into the mouth is mechanically impossible For this purpose the shoulders are raised on a sand-bag, and the head, turned to one side, lies with the face below the level of the larynx A Doyen's gag placed on the upper side of the face, keeps the mouth slightly open, and open administration is practised, allowing full view of the face

* Brit Journ Anæs, 1933 xi i, No 3, p 104

It has been said that only a preliminary tracheotomy or intubation of the larynx, with gauze plugging to cut off the pharynx, can effectively prevent flooding of the air-passages when really copious vomit of thin fluid occurs during operation for long standing intestinal obstruction But the measures outlined above have always proved efficient in my experience Frequent mopping out of the dependent cheek and of the pharynx may be required

Patients suffering from *acute septic infections*, particularly acute septic peritonitis, form another class in which anæsthesia has unusual risks Here the danger lies not only in the extra risk of fatality at the time of operation but perhaps even more in the chance of fatal sequelæ The risk at the time of operation is due to the affection of the heart muscle which may accompany severe infection This toxic myocarditis is detected only with the greatest difficulty beforehand, and yet may play a terribly dominating part in leading to syncope during anæsthesia It reveals itself by no murmur, alteration of the heart s dimensions, or other easily observed physical sign, though it may be suggested by the unusually short snappy character of the first sound Post mortem however, it has often been demonstrated both to the naked eye and histologically, and the clinical disaster has been attributed to it The postoperative risks are mainly of two kinds The patients are liable to secondary shock on recovering from the anæsthetic, or they may later suffer from postanæsthetic toxæmia

POSTANÆSTHETIC TOXÆMIA ; PNEUMONIA

This strange condition sometimes known as *acidosis*, or as *delayed chloroform poisoning*, is most common in children, but occasionally affects adults It has been most frequently associated with chloroform, but has also occurred after the other general anæsthetics Children suffering from septic peritonitis are peculiarly liable if chloroform is used

The true explanation of postanæsthetic toxæmia is still wanting, but is probably to be found in disturbed liver function due to parenchymatous changes The phenomena are now familiar, but their mode of origin remains quite obscure The symptoms usually begin about twelve hours after inhaling the anæsthetic Up to that time the recovery period has usually been normal, and there is no special peculiarity in taking the anæsthetic Vomiting, which at first may seem not unusual and may not have been present at all during the first hours of recovery, persists and produces altered blood, and restlessness, going on to delirium Jaundice sometimes appears The breath often smells of acetone, and this substance, or its precursors, is found in the urine The pulse increases in frequency, and towards the end of a fatal case the temperature is usually high Coma, convulsions and cyanosis are usually the terminal symptoms, and death occurs within four or five days of the inhalation Many patients justly regarded as examples of mild postanæsthetic toxæmia, recover with treatment This consists in washing out the stomach with

bicarbonate-of-soda solution and leaving some in the cavity, and in the administration of glucose per rectum One ounce in 10 of saline suits children of 10 years of age In desperate cases the bicarbonate solution is infused into a vein Post mortem the chief lesion is extensive fatty degeneration of the liver, with a lesser degeneration in the kidneys and the heart The acidosis, evidenced by acetone or diacetic acid or both in the urine, is probably a result of defective functioning of the liver, and an accompaniment, rather than the cause, of the symptoms of postanæsthetic toxæmia Acetone is commonly present in the urine after anæsthesia in small amount Moreover, it has been found often in children during their first days in hospital before any anæsthetic has been administered it is attributed then to change in diet Generally, its presence after operation may be due to pre operative starvation or preparation

The *prevention* of postanæsthetic toxæmia is best achieved by avoiding chloroform in all patients who are the subjects of sepsis, rickets, cyclical vomiting or diabetes, by avoiding preliminary starvation, by allowing plenty of carbohydrate food during the days before operation, and by four-hourly administration of bicarbonate and glucose for twenty-four hours before anæsthesia

If postanæsthetic toxæmia may be regarded as the characteristic formidable sequel of chloroform inhalation, *postoperative pneumonia* may be put in the same relation to ether Just as chloroform is not the only antecedent in "delayed chloroform poisoning," so "ether pneumonia" has followed other anæsthetics, even spinal injection with no inhalation at all The most potent factor is the site of operation Abdominal operations are followed far more frequently by chest complications than any other kind of operation and the anæsthetic employed has but a secondary effect The chief agent of trouble is the inhibition of the diaphragm caused by the laparotomy Partial deflation of the bases of the lungs often follows laparotomy, owing to diminished efficiency of inspiration This often leads to patches of collapse in the lower lobes, and these cases provide a fair proportion of those described as "ether pneumonia"

Another condition sometimes called "pneumonia" is the *massive collapse* described by Pasteur This is a one sided condition, whereas the former kind of collapse, depending on postoperative limitation of the diaphragm's movement, is of course commonly present on both sides Pasteur attributes massive collapse to reflex arrest of one half of the diaphragm, and says that it occurs more often after large incision and division of muscles Massive collapse is of sudden onset, and may be so intense as to suggest embolism or pneumothorax It is rarely fatal in the absence of surgical sepsis There is expectoration of greenish muco-purulent material, which is never blood stained, and rise of temperature The attack begins within the first four days after operation, and the urgent symptoms last only twenty four hours During this time there are dyspnœa and displacement of the heart In the presence of an imperfectly distended lung and inefficient efforts

at coughing, inhaled infective material easily sets up inflammation. The saliva and mucus secreted during ether anæsthesia may convey organisms to the air-passages, and thus ether may be blamed for postoperative lung troubles. Whipple has shown that the pneumococcus is the common organism and that the infection is frequent in healthy people who have shortly before or at operation been subject to a "cold," or some upper respiratory disorder. The pneumococci are of four different kinds, and only one kind leads to serious illness or fatality. The most serious cases are those in which the lung affection is associated with sepsis. These patients are often free from lung trouble till after the first week, and the pneumonia cannot be justly attributed to the anæsthetic at all. It is obvious that in the avoidance of serious postoperative lung troubles it is of the first importance that the patient should be free from any infection of the air-passages at the time of operation.

There are certain *constitutional conditions* in which some anæsthetics are especially dangerous. Thus, in *diabetes*, chloroform and ether may be followed by diabetic coma. Nitrous oxide and oxygen offers less risk. Amputations for diabetic gangrene are well performed under this kind of anæsthesia, often with the assistance of novocain solution into the main nerve-trunks of the limb. The injection is carried out after the exposure of the nerve during nitrous oxide inhalation. An alternative which answers well is spinal analgesia. Nitrous oxide and oxygen may be given concurrently if unconsciousness is desired. In *albuminuria with eclampsia*, for which Cæsarean section is often performed, like considerations hold. Gas and oxygen generally suits the patients undergoing this operation. Preliminary narcotic hypodermics are best omitted on account of their evil effect upon the infant.

Post-operative care.—It is obvious that patients after operation should not be exposed to any temperature much below that of the operating theatre, that they must be kept uniformly warm by the proper covering, and that there must be no sudden changes in position. Generally speaking, they should be gently lifted from the trolley by two or three people and laid in bed on the right side, knees semi-flexed and head resting on bolster or one pillow, being left in this position until consciousness has returned. After that the patient should be allowed to alter the position as inclination suggests and should be encouraged to change sides and to be propped up, providing, of course, that there is no contra-indication to movement. After spinal analgesia, however, perfect stillness, with the head of the bed lowered, is essential for some hours.

NITROUS OXIDE AND OXYGEN IN MAJOR SURGERY

The surgery of 1914–18 gave a great impetus to this anæsthetic, which has already been made available for long operations by the invention of suitable apparatus. For this we are indebted in the first instance to American workers. Hewitt's apparatus, which

previously held the field, was **not** convenient for long administrations because of the number of cylinders, the laborious method of supplying the gas, the liability to freezing at the valves the absence of means for rebreathing, and the tendency for the provision of the gases to become intermittent In the apparatus now used (*see* Figs 1, 3, 4) these deficiencies are corrected, and a visible, continuous flow of gases easily controlled by the hand, supplies a bag from which rebreathing can be permitted at will *McKesson's apparatus* (*Fig* 1) is a further improvement, permitting the admission of either nitrous oxide or oxygen, alone or combined, under pressure Under these conditions it is easy to keep a patient unconscious with gas and oxygen for long periods of time without any anoxæmia It must however, always be remembered that the level of anæsthesia thus obtained is different from and less profound than that induced by the other general anæsthetics Ignorance of this fact leads to disappointment Thus the results so satisfactorily obtained in much of the surgery of the Four Years' War—operations for example, on bones or comparatively insensitive parts, or on shocked individuals easily rendered anæsthetic—were not repeated in civil practice when gas and oxygen was used for an abdominal section in a healthy man Nevertheless, the gases are of the greatest value if their limits are understood and their administration is combined with that of ether or with local anæsthetics or preliminary hypnotics when full relaxation in muscular subjects is required or when sensitive parts are subjected to operation

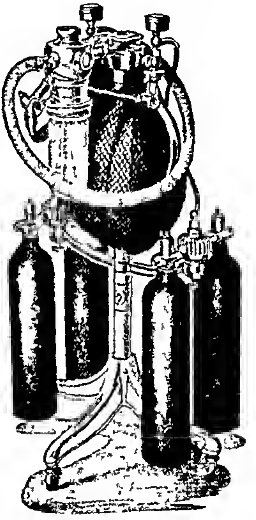

Fig 1—McKesson s apparatus for gas and oxygen

In administering gas and oxygen for major surgery there are a few cardinal rules to be observed First, the face piece must fit with absolute accuracy, secondly, cyanosis is constantly to be avoided by sufficiently free use of oxygen, thirdly, a free airway through the mouth is essential, and fourthly, anæsthesia should be present for

at least a minute before the operation is begun Moreover, ether, which is almost invariably necessary in abdominal operations on adults, unless potent pre medication has been used, should be introduced during the induction period As soon as the patient is unconscious with gas and oxygen, he should be brought fully under ether Then, the ether being turned off, a long period of proper relaxation can be maintained solely by the inhalation of the gases, aided doubtless by the ether imprisoned within the circulation

The possibilities of gas and oxygen without ether for abdominal operations are much extended by the endotracheal method The elimination of laryngeal spasm and of all upper air passage trouble gives relaxation, even during operation on the upper abdomen, with a narcosis so light that it would be insufficient by any other method of administration It is well to remember that the perfect safety of nitrous oxide and oxygen for short operations does not apply when the gases are employed over a long period There are a number of recorded fatalities from their use in major surgery Many of these were, no doubt, in reality inevitable, whatever anæsthetic had been employed Nevertheless, there is distinct risk in the use of gas and oxygen during major operations, unless the administrator is highly skilled The risk is especially great with children, and with adults whose heart action is faulty Generally speaking, ether is safer for persons with dangerous heart disease Physicians are very apt, on theoretical grounds, to recommend nitrous oxide when it is, in practice, the more dangerous agent When gas and oxygen is to be the sole anæsthetic, it is always best preceded by hypodermic injection of morphia and atropine, or omnopon and scopolamine, or some similar combination, unless the patient's general condition presents a contra indication The carbon dioxide absorption method should be used for all long administrations (*see* p 85)

Patients in a condition of shock at the time of operation are best treated with nitrous oxide and oxygen or with warm ether vapour and oxygen War surgery showed that chloroform was very dangerous for these patients, and that contrary to expectation, the same was true of spinal injection One great advantage of gas and oxygen in shock is that the rapid recovery without nausea enables the patient to drink liquid stimulants soon after operation This measure, and careful preservation of the body-heat, with continuous infusion of gum-arabic saline from the beginning of administration, are the most effective means of combating shock The anæsthetist's concern with shock is to prevent it when possible, to combat it when present, and to avoid everything that might predispose to postoperative shock To avoid shock arising during operation, the anæsthetist's chief measure is to limit the dose of ether or chloroform Each of these, given over long periods or in excessive strength, may cause a condition almost identical with surgical shock Similarly, postoperative shock, so far as it depends on the anæsthetist, is chiefly obviated by avoiding excessive dosage The reactionary collapse that follows too-liberal

use of open ether is an example of the power of the anæsthetic to produce shock. Experimental evidence proves that excessive trauma on the one hand, or anæsthetic overdose on the other, leads to functional inactivity. The former produces exhaustion by repeated stimulation; the latter, by the continued depressing effect of the anæsthetic drug. The surgeon by gentleness, and the anæsthetist by careful limitation of his doses, combat the shock produced by trauma and by anæsthesia.

ROUTINE ANÆSTHESIA

Administration.—It is not within the scope of this article to describe in detail common methods of administration of anæsthetics. Some general principles may, however, be pointed out. The first in importance is that there must always be unobstructed freedom for ingress and egress of the anæsthetic during inhalation anæsthesia. Many troubles arise from neglect of details which are essential for securing an unobstructed air-entry.

The first is careful inspection of the patient. Not only must it be clear that respiratory movements are normal, but also the interior of the mouth must be examined, to discover whether the shape of the palate and the arrangement of the teeth will lead to obstruction. A high, narrow palate, or a full set of accurately meeting teeth, or an underhung lower jaw means that any congestion or spasm of the upper air-passages will lead to obstructed respiration. In persons who show these peculiarities a small prop must always be placed between the bicuspids of one side before commencing anæsthesia. This will enable free oral respiration to go on even if the nose is insufficient, and will allow the easy insertion of a gag, to be opened if still more room in the mouth becomes necessary.

The next point is to see that the head is slightly raised above the level of the shoulders and turned to one side. Few persons go to sleep easily if they are horizontal; yet that is often the position in which they are expected to inhale an anæsthetic. The lowered head tends to keep the brain well supplied with blood and to delay narcosis. The need for quiet during induction is now commonly recognized. It is due to the fact that the sense of hearing persists and even seems accentuated during induction. At the same time, reasoning and the power to co-ordinate stimuli disappear, so that the slight noise—of moving instruments, for example—may convey to the semi-conscious patient a terrifying impression that will be revealed by reflex depression of pulse and respiration. When it is necessary to move a patient during anæsthesia before operation, he must be deeply under; otherwise vomiting is easily excited. Similarly, alteration of position during operation, especially if sudden, may have grave consequences if the patient is suffering from shock. The vaso-motor mechanism, which compensates for the effects of gravity and prevents all the blood rushing to the dependent parts, is out of action during deep narcosis.

Combinations of anæsthetics.—The anæsthetist of to-day has at his disposal several drugs and a great many different modes of administering them. Moreover, he often finds it an advantage to combine both the drugs and the methods. Thus, instead of merely preceding ether by nitrous oxide or by ethyl chloride, or giving chloroform or one of its mixtures, he may use alkaloids, a spinal injection and continuous nitrous oxide and oxygen for one patient; or the latter anæsthetic may be combined with local injections for another; or he may employ colonic ether and a warm-vapour inhalation of chloroform and oxygen. He may prefer a rectal injection of avertin or an intravenous one of nembutal or evipan. It is probable that local analgesics in association with general anæsthetics will find increasing favour in the future. The advantage to the patient is great The general anæsthetic is used merely to obtain and maintain unconsciousness Consequently, nitrous oxide and oxygen usually suffices; or, if ether is required, it can be used very sparingly. Relaxation of muscles depends on the local injections, not on the inhaled anæsthetic. For long operations, and those usually accompanied by shock, the method is admirable when it can be applied. The patient is saved much of the shock, as Crile especially has shown, if peripheral impulses can be cut off by local infiltration of nerve-endings, and he suffers none of the prostration or vomiting that is so likely to follow long administrations of a general anæsthetic used to maintain deep narcosis. The local anæsthetic usually employed is novocain, and large quantities of solution may be needed, but this may be as weak as ¼ per cent Quinine and urea chloride, at one time much used for deep injections, has undoubtedly caused tissue necrosis, and led to the extrusion of deep sutures. Percaine is likely to prove most useful, though pain may be caused at the time of injection.

The combination of narcotics, given hypodermically beforehand, with inhalation anæsthesia, has become so general as to be a routine with many anæsthetists. There appears to be no contra-indication to routine use of *atropine*. It has been argued that even this drug should not be given indiscriminately, and that its paralysing action on glandular secretions may interfere with proper elimination of the anæsthetic. We know, however, that anæsthetics are eliminated almost entirely by the lungs, and atropine does not interfere with this. On the contrary, it exerts a certain amount of stimulating effect on the respiratory centre and thus, by maintaining ventilation of the lungs, may be expected to assist elimination.

Drugs such as *morphia* and *scopolamine* are not suited to routine use. Some surgeons object to them altogether for abdominal work, on the ground that they make muscular relaxation more difficult. It certainly takes longer to get the patient relaxed when he has had the injections, because respiration is slowed and, consequently, the anæsthetic is more deliberately inhaled. The effect of these drugs upon the respiratory centre, which they depress, is a strong reason

against their routine employment Recovery from unconsciousness is long delayed when morphia and scopolamine have had their full effect This delay, accompanied by very slow breathing, exposes the patient to the dangers of poor ventilation for hours These drugs act to greatest advantage in highly nervous individuals and when the abdomen is not involved Before a cystoscopy the anæsthetist must remember not to order narcotics hypodermically, for, if they are used, secretion from the ureters may be watched for in vain In the aged, I believe, morphia in combination with anæsthetics is dangerous Lastly, some patients suffer from sickness and faintness after morphia or scopolamine In the absence of any previous history, it is not possible to detect this idiosyncrasy Occasionally, the injection has produced so much pallor and feebleness that the projected operation has had to be postponed It is said that untoward symptoms in an adult have never followed an injection of morphia not exceeding gr $\frac{1}{6}$ In the absence of any knowledge of the patient's behaviour towards morphia, it is wise to restrict the preliminary dose to this amount scopolamine is commonly given in doses of $\frac{1}{150}$ grain Omnopon may certainly be given without harm to some who have been upset by morphia It has been maintained that narcotics which depress the respiratory centre should only be given if the anæsthetic is to be administered by a method involving rebreathing so that the carbon dioxide will stimulate the centre in counteraction to the narcotic s depression

Carbon dioxide is given to stimulate breathing and increase pulmonary ventilation It is used to hasten induction by causing exaggerated intake of the anæsthetic and it is used at the close of, or after, operation to hasten elimination of the anæsthetic and reduce the chance of pulmonary complications by causing full distension of the lung bases Carbon dioxide for these purposes is best given from a cylinder in which it is contained with oxygen in the proportions of 7 per cent CO_2 to 93 per cent O A breath of pure CO_2 may be conveniently given from the sparklet apparatus shown in Fig 2

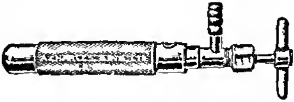

Fig 2—Apparatus for giving pure carbon dioxide

The routine anæsthetics recommended for ordinary operations are nitrous oxide and oxygen and ether Gas and oxygen will be used for short operations and those for which perfect muscular relaxation is not essential When relaxation is essential and in all abdominal work, it must be supplemented by ether or C E mixture, unless a powerful hypnotic like avertin has been used beforehand This combination is the best routine anæsthetic for abdominal operations Even then resistant patients need something in addition to the gas and oxygen Some short operations which are not well suited to gas and oxygen—for instance, rectal and uterine procedures—are satisfactorily

managed by gas and ether There is little objection to this comparatively old fashioned method for short operations in healthy subjects

Good apparatus for prolonged administration of nitrous oxide and oxygen is now made in this country after the designs of Marshall, Boyle and Shipway (Fig 3) The Walton apparatus (Fig 4) is after the McKesson type The important points are that the cylinders of nitrous oxide and of oxygen are placed vertically, that there is very delicate control of the valves which allow the egress of the gases and that the gases are bubbled through water, so that their amount and rate of flow are easily seen in the "sight feed" apparatus (Boyle and Shipway) A flow-meter is an even better means to this end Rebreathing is used from the start and freely throughout the administration (but not with the McKesson type)

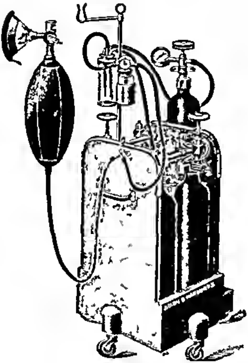

Fig 3 —Boyle's nitrous oxide and oxygen and ether apparatus

Perfect accuracy in adaptation of the face piece is necessary, and is generally secured by a loop of elastic passing round the back of the head and fitting round each side over the metal mount of the face piece, where it is secured beneath the mount from the bag, or by the use of Clausen's rubber harness The proportions of the gases commonly needed are those obtained by having two of the oxygen holes and four of the nitrous oxide holes open With the McKesson apparatus the dial is placed for the first few breaths at N_2O only, and the gas delivered under pressure without the face-piece being close to the face Then it is fitted on and the dial moved to give at least 5 per cent oxygen at first The bag with the sight-feed apparatus should be at some tension for the first few minutes It should be filled to about two thirds of its extent before the face piece is applied Rebreathing being instituted at once the tension of the bag will of course increase as the gases flow in Every few minutes rebreathing is stopped by opening the expiratory valve, and the bag is allowed to empty itself to about one third of its full size In this way too great an accumulation of carbon dioxide is avoided

A word of warning may be given on one practical point If the oxygen tap moves stiffly no vaseline or oil must on any account be used to ease the joint If any such material is in the immediate neighbourhood the heat generated when oxygen escapes from the

cylinder and meets the reducing valve or the pressure-gauge as the case may be, is enough to flash the oil in the grease. Then the yellow metal may fuse and, fed by the oxygen, the flame may even fuse the cylinder, with very serious results. Soap may be safely used as a lubricant.

Ethylene is given from cylinders and apparatus exactly similar to those used for nitrous oxide. It is employed, however, with much larger percentages of oxygen, usually about 15 to 30 per cent. oxygen being given with the ethylene after the first few breaths which should be almost without oxygen. The anæsthesia produced by ethylene is more profound than that of nitrous oxide but less than that of ether. It appears to be as innocuous to the tissues as nitrous oxide. It has more relaxing power than the latter but less than ether. When used for abdominal operations some ether has generally to be added to secure perfect relaxation. Owing to its unpleasant smell and the risk of explosion, special precautions have to be taken.

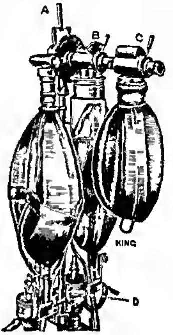

Fig. 4.—The Walton apparatus.

Cyclopropane (trimethylene C_3H_6) is a potent anæsthetic given from cylinders in the same way as nitrous oxide. It has the advantage that it is not irritating and is efficient with large oxygen dilution, 10 per cent. of cyclopropane for light anæsthesia and 14-16 per cent. for full relaxation being the strengths commonly needed. Cyclopropane is explosive at certain strengths in air, oxygen or nitrous oxide, and is not to be used in proximity to the cautery, diathermy apparatus or open flame. It is of special value for major intrathoracic operations owing to the large amount of oxygen it permits. It must always be given by a closed circuit method with *carbon dioxide absorption*. This technique is advisable with most nitrous oxide apparatus, not only for its great economy but because of the perfect control it gives over the patient's respiration. Also, respiratory heat loss and water vapour loss are greatly diminished and no anæsthetic vapour pollutes the air of the theatre. The method requires the interposition near the face piece of a soda-lime filter containing Wilson soda-lime 4–8 mesh. The container should be 12 cm. long and 8 cm. in diameter. Cyclopropane easily stops respiration and the practitioner should not employ it until he has learnt its use from an expert.

Ether, for routine purposes, should be given by the open method or as a warmed vapour. The latter is not well suited for induction of anæsthesia, the draught of the in blown vapour being disconcerting to the conscious patient. Open ether itself, when used from the beginning, takes a needlessly long time with robust adults, so they are best induced with C.E. mixture, as soon as consciousness is gone

best started with C E mixture, as soon as consciousness is gone vapour apparatus (Fig 5) affords an excellent means of maintaining anæsthesia, as a regular supply of uniform vapour is easily kept up The only drawback is that, with difficult subjects, the vapour supplied may not be strong enough Then either additional ether may be dropped on the mask, or the chloroform bottle of the apparatus may be brought into play Sometimes merely covering the mask with a towel, so as to enforce a certain amount of rebreathing, will suffice The pendulum of practice which swung violently from closed to open ether, now shows some signs of returning The best practice appears to lie in com promise the open method is used with modifications that render it partly closed The mask is covered wholly or partly with a thick towel, or with water proof sheeting, in which a hole is cut for the ether There are both theoretical and practical justifications for these devices Theoretically, Yandell Henderson's views on the causation of an undesirable degree of acapnia with the open method suggest that it be employed with caution Practically, it is often impossible to maintain a deep narcosis with strictly open ether Another reason against the strictly open method is the coldness of the vapour, a little rebreathing warms it

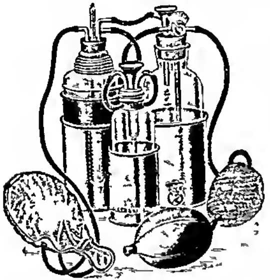

Fig 5 —Shipway s warm vapour apparatus for ether and chloroform

This adds to the efficacy of the administration, for the cold caused by evaporation on a partly open mask lessens the rate of evaporation of the added ether Much advantage has been claimed for warm anæsthetic vapours they are said to be at once less toxic and more efficacious This is hard to understand, but it is easy to realize *that for a very feeble patient it may be important to preserve even* the small amount of body heat which is expended on warming a cold vapour up to blood heat, and a warmed vapour is less likely to irritate the upper air passages Actually it appears true that, whatever temperature the vapour has when inhaled, it is warmed to blood heat before it has passed the bifurcation of the trachea *

The closed method of giving ether from a Clover's inhaler is too useful in general practice to be allowed to drop out The practitioner who makes himself competent in this simple procedure can give a safe and efficient anæsthesia for a large proportion of ordinary operations The method is applicable to all persons with sound heart and lungs,

* The recently introduced Oxford vaporiser provides definite percentage strengths of warm ether vapour and is likely to be widely used.

and is not unpleasant when the anæsthetist has mastered the simple technique and proceeds slowly in the early stages It is best preceded by atropine, gr $\frac{1}{100}$, three quarters of an hour beforehand

Endotracheal ether is of great value in extensive operations involving effusion of blood within the air passages, e g excisions of tongue or of malignant growths of tonsils or of naso-pharynx The method is also almost indispensable during certain cerebral operations which require the head to be in extreme flexion, and for some operations within the mouth The patient is brought into deep anæsthesia by one of the ordinary methods an open one being generally preferable The anæsthesia must be deep so that there may be no gagging and no spasmodic approximation of the vocal cords when the catheter is passed through the larynx A laryngoscope with a wide slot at the side and a self contained battery in the handle is the most convenient instrument for introducing the catheter To pass this easily, the patient's head is placed in the midline, the neck and head keeping their natural relation to the chest, not flexed or over extended The masseters being quite relaxed by the proper anæsthesia, there is frequently no need for a gag or tongue-clip, the slotted spatula of the endoscope being easily passed along the dorsum of the tongue by the anæsthetist's left hand, grasping the handle of the instrument which is depressed to disengage the tip of the spatula from the epiglottis At the same time the instrument is pushed on towards the posterior wall of the pharynx If now the handle is raised, pressing its end against the anterior pharyngeal wall the glottis should come into view No attempt is made to pass the catheter until the cords are clearly seen When this is done the catheter is easily run along the slot in the spatula, into the larynx and down to the bifurcation of the trachea The catheter should be marked to show how far it is to be passed in the average adult The distance is about 26 cm from the front teeth to the tip of the catheter in male and 2 or 3 cm less in female subjects The size of the catheter is about 22 French The larger the catheter, the deeper the anæsthesia There must always be room alongside the catheter for the free escape of expired air When the catheter has been inserted and the anæsthetist is certain that it is down the trachea and not the œsophagus, it is connected up with the efferent tube of the apparatus to be used for administering the ether Shipway's is a convenient form Whatever apparatus is employed it must have certain qualities (1) a source of air supply—hand pump, foot-bellows or electric motor (2) tubes to and from the ether reservoir, (3) a mercury manometer showing the pressure at which vapour is delivered into the trachea, and an automatic regulator to blow off when the pressure is excessive, (4) a warm water tank to moisten the stream of air before it reaches the lungs The manometer is set to blow off at 20 mm Hg, or a little more The machine should deliver air at the rate of about 16 litres per minute It is possible, but not advisable with intratracheal insufflation, to bring the respiratory movements entirely to rest and yet continue the oxygenation of the body It is quite possible

to use intratracheal methods without any pumping apparatus at all and, generally speaking, no high pressure should be employed Magill has shown that, by introducing a tube that fills the glottis, anæsthesia can be well maintained simply by a mask over the external end of the tube and a drop-bottle The tracheal tube is passed merely to eliminate all laryngeal and upper air-passage difficulties Magill has also shown that to pass the intratracheal tube by the nose is often easier than by the mouth No laryngoscope is then required Commercial rubber tubing of sizes from $\frac{3}{8}$ to $\frac{3}{16}$ of an inch in calibre is used It is curved, cut obliquely, sterilized and lubricated with soft paraffin The tube is passed along the floor of the nose, close to the septum Deep anæsthesia is not necessary before passing the tube and is not an advantage. Gum elastic catheters up to size 28 (French) may be used if preferred to the tubing The more patent side of the nose is chosen for the passage of the tube

Rectal or colonic administration of ether, by an ether oil mixture, is not suited to routine use because the dosage cannot be controlled with sufficient accuracy The conditions are very different from those present when the drug is being given all the time in a manner which can be strengthened, weakened, or stopped at a breath, as the patient s condition demands It is true that rectal ether can be augmented in its action if necessary, by covering the patient s mouth so that the vapour is not briskly expelled but is re-breathed to some extent, or, on the other hand when narcosis is too deep, the ether-oil can be drawn off by keeping a tube in the rectum These measures do not, however, allow the same graduation of doses that is possible with inhalation After effects that sometimes arise are distension of the bowel, tenesmus, or diarrhœa with some blood When this method is employed the bowel should be washed out with soap and water after operation To leave a couple of ounces of olive oil in the rectum after this is thought, by some authorities; to enhance the patient's safety and comfort The administration of ether vapour by itself per rectum has recently been advocated Experience is not yet wide enough to determine its value It was in this way that Pirogoff, as long ago as 1847, originally tried rectal ether

The mixture consists of olive oil and ether, the strength of ether never being greater than 75 per cent for adults and 50 to 65 per cent for children and feeble subjects Not more than 8 oz of the mixture is to be used The dosage may be reckoned as 1 oz of the oil-ether mixture for every 20 lb of body weight An aperient is given the night before operation day and water enemata on the morning of that day, until the return is clear One hour before the injection, 2 to 4 dr of paraldehyde with an equal amount of olive oil are administered per rectum Hypodermic injection of morphia or of omnopon and atropine may be substituted if preferred The washing out of the rectum should be completed at least two hours before operation time Half an hour before operation the rectal injection should be made The patient lies on his left side in bed with the knees bent A soft rubber

tube, already filled with the mixture, is passed up the rectum for six inches The mixture is poured through a funnel at the rate of not more than 1 oz per minute Narcosis may be increased by placing a towel over the patient s face or, during face operations, more anæsthetic may be supplied by inhalation from the tube of a Shipway or Junker apparatus If, as is rarely the case, narcosis is too deep, a tube must be passed up the rectum to withdraw any of the mixture still there Precautions to ensure a free air-way are just as important as during ether inhalation After operation two small soft tubes should be passed, to wash the rectum free by injecting cold soap and water up one tube and allowing it to escape from the other

The *risk* of colonic ether administration is mainly confined to unhealthy states of the bowel The anæsthetist must be perfectly certain that the rectum and colon are normal Disaster has followed the use of the injection for a patient who had concealed the fact that he was subject to dysentery Fatalities have also been recorded that are apparently due to the toxic action of ether Strict limitation of dose, freedom of air way, inhalation of oxygen, and if necessary, artificial respiration should however render such mishap almost impossible

Administration of ether by swallowing was tried on many patients in military hospitals during the Four Years War Analgesia may be obtained, but not true anæsthesia, unless in exceptionally susceptible subjects The method was useful for painful dressings Ether was given with liquid paraffin (½ oz of each), accompanied by pepper and salt and lime juice or, sometimes, port wine

Intravenous infusion of ether requires special apparatus to ensure that the solution is applied in a slow, steady stream without the possibility of air-bubbles The instrument designed by Rood is perfectly satisfactory The method is only recommended where addition of fluid to the circulation is desirable Hedonal and isopral were both tried extensively by infusion without approval Fatalities accompanied the too-long coma which follows these agents, as well as medinal

Intramuscular injection of ether, without presenting any advantage over other methods has the drawback that it may lead to sloughing

Vinethene (divinyl ether) is an admirable anæsthetic for short operations and for supplementing nitrous oxide in long ones It is much less irritating than ethyl ether and not unpleasant It is so volatile that it cannot be given conveniently by the open method, but when given from closed apparatus must be freely diluted with air or with oxygen, as it is extremely potent in high concentration

Ethyl chloride is of routine use either (1) for operations so short that they can be performed after the administration of a single dose of the drug, or (2) as a preliminary to ether or chloroform mixtures For short operations it is given in doses of from 2 c c for a small child to 5 c c for an adult male The most effective plan is to use the face-piece and small bag of Clover s inhaler The bag is fitted with a mount which carries a small tube holding the ethyl chloride so that

this is readily tilted into the bag Used in this way with the bag mounted on a Clover's inhaler ethyl chloride is also very useful as a preliminary to ether for persons who are not conveniently managed with nitrous oxide Squirted on to an open mask the drug is most useful for rapidly inducing unconsciousness in crying frightened infants or in young children who are to be anæsthetized with ether or chloroform mixture

Abrand* designed an apparatus for prolonged narcosis by ethyl chloride It is doubtful however whether the anæsthesia obtainable is so uniform or so safe as that which can be secured by ether or gas and oxygen

Chloroform which remains in certain cases of severe respiratory embarrassment the anæsthetic of choice is best given by an apparatus such as that of Junker or of Shipway which enables the anæsthetist to supply a uniform and strictly controlled vapour When the administration must be with chloroform throughout it is best begun with a drop-bottle and open mask If the anæsthetist keeps up a continuous supply of drops into the mask but never lets this touch the face he will run no risk of overdose The vapour thus supplied if kept very dilute is less irritating than the draught from an apparatus which is substituted directly the patient is sufficiently under the influence of the drug to be insensitive to what he inhales

Evipan and pentothal are two barbiturate anæsthetics which given intravenously are admirable for short operations when full relaxation is not needed The necessary 5 per cent solution is made fresh from two ampoules in which the drug and distilled water are supplied It is injected into a vein of the arm at the rate of 1 c c in 15 seconds until consciousness is lost and then half the amount injected is added The arm must be safely fixed and care must also be taken that the airway is not obstructed by spasm of the jaws which is not uncommon Usually induction is perfectly quiet and is often introduced by a yawn Unconsciousness comes on rapidly Recovery is also rapid but there may be restlessness or an intoxicated condition lasting some hours for which reason patients should not be allowed to go away from supervision soon after a minor operation under these quickly acting barbiturates

Longer operations can be performed under these drugs by leaving the needle *in situ* and adding doses as required Special apparatus for the introduction of continuous saline solution is needed The method does not appear to have advantages over the more usual gaseous agents

BASAL ANÆSTHETICS

The practice of giving some preliminary sedative before an anæsthetic has been extended by the introduction of basal anæsthetics which have two chief purposes (1) to prevent all harmful psychic effects by means of an easy induction of unconsciousness carried out

* [illegible]

while the patient is still in bed (2) to diminish greatly the amounts of toxic anæsthetic required and to enable most operations to be carried out merely with the additional aid of nitrous oxide or other gaseous anæsthetic

The basal anæsthetics in common use are paraldehyde, avertin and various barbiturate preparations, the most recent of which are evipan, pentothal and nembutal, which bid fair to replace the older amytal and pernokton Paraldehyde and avertin are given per rectum Nembutal is given either intravenously or by the mouth Evipan and pentothal are given intravenously Paraldehyde is given at a dosage of one drachm per stone of body-weight of the patient, with half an ounce of olive oil per drachm of the drug It is introduced into the rectum an hour before operation and a hypodermic of omnopon or corresponding drug is usually given half an hour earlier

Avertin is given in doses of about 0 1 gm per kilo of bodyweight, which is roughly $\frac{2}{3}$ gr per stone, in a 3 per cent solution with water No other preliminary drug should be used unless the patient is alcoholic or very resistant The dose should be injected three quarters of an hour before operation, and should be run in within 5 to 10 minutes Within fifteen minutes there are generally unconsciousness, contracted pupils and shallow automatic respiration Care must be taken to prevent mechanical obstruction of the air way from falling back of the lower jaw and tongue

Nembutal is supplied in ampoules of $7\frac{1}{2}$ gr which are dissolved in 10 c c of distilled water, for intravenous use, though the whole of this is hardly ever required A 10 c c syringe with a fine needle is used and the injection, made at the rate of 1 c c per minute, need not be begun until ten minutes before operation The dose is the minimum amount needed to produce sleep, which comes on rapidly and quietly, as soon as it occurs the administration must be discontinued Capsules of $1\frac{1}{2}$ gr are supplied for oral or rectal administration This should take place half an hour before operation Drowsiness lasts from one to five hours after operation There is restlessness in some patients

All the basal narcotics are to be used with caution The great advantage which they offer to nervous persons must not be allowed to obscure the fact that they do to some extent increase postoperative risk unless the amounts given are very carefully controlled

SPINAL ANALGESIA

The value of spinal analgesia in suitable cases cannot be overstated Occasionally, operations have to be performed on patients whose lung condition renders inhalation, even if possible, extremely undesirable Amputation for diabetic gangrene is an operation for which spinal analgesia is often the best anæsthetic Experience has shown that the Trendelenburg position, if not instituted until at least five minutes after the injection, can be quite safely used with spinal analgesia

Occasional failures when there is no doubt about the fluid having been properly injected into the intra arachnoid space have been attributed to faulty glass ampoules Occasional partial failure is the bugbear of all local anæsthetic measures and cannot always be put down to faulty technique its most common cause

It must be remembered that a spinal injection on the perfectly conscious patient is never painless Therefore preliminary injections of omnopon and scopolamine or similar drugs enough to dull sensibility should always be used unless there is grave reason to the contrary In many cases where spinal injection is desirable particularly for complete muscular relaxation it is perfectly admissible to secure unconsciousness first in the ordinary way or by a basal narcotic afterwards giving only enough of the general anæsthetic to maintain unconsciousness without any depth of anæsthesia This is often the best practice in operations for removal of the prostate and for Wertheim s hysterectomy The spinal injection is made with the patient sitting or lying on the side The recumbent position must always be used with the unconscious patient the sitting position is easier for the injection In either case the object of the position is to secure the greatest possible flexion of tho back in order to increase the space between the spinous processes The space selected for the puncture and injection is generally that between the 2nd and 3rd lumbar spines or between the 1st and 2nd or the 3rd and 4th The method is best confined to operations below the umbilicus The space desired is found by means of the fact that a line drawn across the back from the summit of one iliac crest to the other passes over the spinous process of the 4th lumbar vertebra The anæsthetist s hands the puncture area his implements and everything he touches must be as surgically clean and guarded as the operation itself Sterile towels must be fastened over the iliac crests for palpation If an ampoule is used it must be held and broken by nurse or assistant so that the anæsthetist s hands are not contaminated Barker s solution (stovaine 10 per cent glucose 5 per cent distilled water 85 per cent) kept in hermetically sealed ampoules which provide 6 cg of stovaine in 2 c c of solution is a very satisfactory agent The syringe hollow needle and cannula associated with the same surgeon s name are perfectly efficient implements for making the injection The spinous process just above the space to be entered is palpated with the forefinger of the left hand The site of the proposed injection and its track to the dura are first injected with novocain solution from a hypodermic syringe

The hollow needle without the syringe is applied close to the skin of the back at the desired point pressing up slightly against the pulp of the left forefinger and then with a sharp push is made to penetrate the skin and interspinous ligament This puncture must be absolutely in the midline The stylet is withdrawn and the needle pushed in through the dura mater giving almost the sensation of piercing paper Cerebro-spinal fluid escapes either in a small spurt or in drops About

as much is allowed to come out as the quantity of solution to be injected. The cannula is now passed down the hollow needle and the injection made with firmness, but not suddenly. The depth to which the needle has to be pushed varies with the fatness of the back; generally, it is between one and two inches. If no cerebro-spinal fluid escapes, the injection should not be made. Nor should the needle be pushed blindly about in the bope of striking the desired space; rather should it be withdrawn and a fresh puncture made. It should be borne in mind that the more forcibly the injection is made, the higber is likely to be the analgesia obtained, and that the more of the stovaine solution used, the longer the analgesia lasts. With usual doses (about 5 cg.) analgesia commonly lasts about an hour. It is often advisable, especially in old men having the prostate removed, to reduce the dose to 4 or 3 cg. Analgesia appears within ten minutes after injection. When the injection has been made the needle is withdrawn slowly, a small pad of sterile dressing is fastened over the puncture with collodion, and the patient laid on his back. The head and shoulders should be slightly raised on a pillow, and a sand-bag placed behind the buttocks to localize the injection to the most dependent part of the back. After five minutes it is no longer necessary to keep the head raised. In fact, if the Trendelenburg position is required, it can safely be employed after this interval.

The *danger of spinal injection*, although not often demonstrated, is that inherent in all injection methods: if by any chance the dose used is exeessive, there is no means of extracting any part of it. In the course of many hundreds of injections there occurs sooner or later an unexpected collapse. This is probably to be attributed to the power which injected analgesics have of lowering blood-pressure. Short of fatal collapse, there are occasionally pallor and faintness, or a condition resembling " air-hunger," which may need artificial respiration. It is noteworthy that these drawbacks to spinal analgesia are less common with improved technique, and particularly now that the head and shoulders are no longer kept raised for long periods after the injection.

Recent work has shown that with novocain and allied drugs there is no fear of paralysing the respiratory centre, even if the injected dose travels up in the cerebro-spinal fluid. This does not apply to stovaine. Novocain is now being used fearlessly for operations above the umbilicus, indeed by some for operations in any part whatever.

Postoperative dangers from spinal injection are very variously estimated. Neurologists maintain that they see numerous instances of nerve trouble which have been started by spinal injection. Anæsthetists hold the view that these are rare unless the technique of injection is faulty. Headache and sixth-nerve palsy are common, but transient, sequelæ.

Percaine is a non-toxic and highly effective local anæsthetic. It is put up in ampoules and used in solution of 1 : 1500 saline. Only a little cerebro-spinal fluid is allowed to escape and then a dose up to 20 c.c. of the percaine solution is slowly injected. This maximum dose gives an

anæsthesia up to about the 2nd dorsal segment Lesser amounts are used when no high level of anæsthesia is needed *

A great advantage of percaine is the increased length of anæsthesia it gives compared with novocain and stovaine

Sacral analgesia has now had considerable trial and may be regarded as a useful alternative to spinal analgesia for operations on the genital and rectal regions and the lower limbs It is probably freer from risk than intrathecal injection On the other hand, the analgesia takes much longer to produce and larger quantities of solution are required The injection may be difficult owing to the variability of the landmarks which indicate the site of the puncture—the sacral hiatus through the membrane guarding the sacral canal This hiatus is situated between the two bony knobs which represent the cleft 5th sacral laminæ Sometimes they are plainly felt and the depression between them is easily entered by the needle Sometimes, on the other hand, the 5th sacral spine is not represented by two equal prominences, but may be mostly composed of one mass at the side of which is the opening In fat persons, again the bony prominences may be very difficult to palpate They are usually about an inch above the tip of the coccyx which is easily palpated in the anal cleft between the buttocks The finger running up from here meets the sacral hiatus guarded by the two bony knobs representing the 5th sacral spine The needle is pushed in vertically for about ½ in and then depressed till it lies in the axis of the sacral canal when it is pushed farther on If it has entered the canal it is easily movable from side to side but hardly at all from before backwards The needle should be pushed up about 2 inches No fluid should escape The syringe is then fitted on and the injection made 2 per-cent novocain with 20 drops of adrenaline solution (1 10 000) for every 100 c c of novocain At least 40 c c of the mixed solution is generally needed The patient lies comfortably on one side there is no need to arch the back but the knees are best slightly flexed If the operation is on one side, as for example for a hernia the patient should lie on that side while the injection is made When the solution is thrown in there should be no swelling or œdema If this occurs it shows that the sacral canal has not been entered and the injection is being made superficially, which will of course, give merely a quite local analgesia and no blocking of the nerves When the injection is properly made, the sacral and coccygeal nerves are blocked Large quantities of the solution can be made to travel up the spinal canal and although outside the dura mater to affect the posterior roots as they emerge so that quite high levels of anæsthesia may be obtained Experience is not yet sufficiently extensive to declare these high injections perfectly safe Convulsive attacks the explanation of which is not obvious, have attended the injection of large amounts of novocain solution into the sacral canal.

The injections are made with the same strict cleanliness as with

* For details the reader should refer to *Proc Roy Soc Med* May 1930 No 4, xxiii 919 and *Canad Med Assoc Journ.*, 1935 xxxiii, 169

intrathecal injection It is always advisable to precede the puncture with a sedative hypodermic injection an hour before The ordinary Record syringe and needle is a perfectly satisfactory instrument, but the needles must be reliably strong, for it is easy to break them in the firm fibrous tissue about the sacral hiatus

Peridural anæsthesia is allied to sacral analgesia but applied to higher levels of the spine It aims at getting analgesia by injections which do not enter the cerebro-spinal fluid They are made into the peridural space and affect the roots of the spinal nerves *

LOCAL ANALGESIA

Local analgesia is produced either (1) by *surface application*, used only for mucous membranes e g in the nose, larynx and eye, (2) by *infiltration*, the tissues being saturated with the anæsthetic solution layer by layer, or (3) by *conduction* or *regional injection*, when the solution is applied to the nerve trunks thus rendering insensitive the regions supplied by them In practice a combination of infiltration and regional injection is commonly employed Obviously, for the proper use of regional analgesia, an accurate knowledge of anatomy is essential A full description of local analgesia is not within the scope of this article Generally speaking it may be stated that although there are few operations which cannot be performed under local analgesia yet it is best reserved for superficial procedures, e g tracheotomy, some strangulated hernias and the removal of digits, or of tumours beneath the skin *In combination with general anæsthetics* however, local analgesia has a wide application and greatly enhances the value of these drugs This is because severe operations can then be performed under nitrous oxide and oxygen alone, thus saving shock and after sickness or under greatly reduced amounts of ether or chloroform For severe abdominal operations gas and oxygen alone is never sufficient If however the surgeon infiltrates novocain into the skin then into the muscles and finally into the peritoneum, often no general anæsthetic beyond nitrous oxide is needed Again, in operations for exophthalmic goitre it is a great gain to reduce to a minimum *the inhalation of general anæsthetics Indeed*, no general anæsthetic at all may be required if the patient is first given a sufficiently large dose of narcotic hypodermically, and then local analgesia The most widely useful local anæsthetic is novocain with adrenaline There is practically no limit to the amount of ½ per-cent solution that may be injected Percaine gives a more lasting analgesia than novocain but, being acid, is just a little painful at first

Splanchnic analgesia is of great value for severe operations on the upper abdomen A quantity of novocain solution is put in contact with the solar plexus by an anterior (Braun) or posterior (Kapp s) route In the first the abdomen is opened under general anæsthesia or a field block, the aorta gently retracted, and 70 c c of 0 5 per cent

* For details see Medical Annual, 1936 and 1937 p 27

novocain are injected in close contact with the lateral aspect of the body of the first lumbar vertebra When the posterior route is used the patient is given a preliminary sedative and is placed on the side, with a small pillow under the loin The spinous process of the first lumbar vertebra is located and a point taken 7 cm external to it, just below the lower border of the first rib A needle (12 cm long) is introduced at an angle of 45° to the median plane and its point should strike the side of the body of L_1 The needle is then partly withdrawn and reintroduced in a more forward direction until its point slides tangentially past the body of the vertebra It is then pushed in 1 cm further and, aspiration being negative, 20–30 c c of 1-per cent novocain are slowly injected The patient is turned on to the other side and the process repeated The abdomen is then opened under field block or a short general anæsthetic, as seems best

Avoidance of shock.—The avoidance of shock during and after operation is largely within the control of the anæsthetist It remains with him to choose the anæsthetic and method best calculated to arrest shock to see to continuous saline infusion, preservation of bodily warmth and the most appropriate posture during operation and to suggest treatment after operation There is no doubt of the efficacy of continuous saline infusion if it is started from the beginning of the operation The supply of fluid and the preservation of bodily warmth are the most effective measures to prevent and combat shock The saline infusion is made into the loose axillary tissues on each side by Lane s simple apparatus Blood transfusion is the most effective form of fluid substitution Bayliss s gum arabic (6 per cent in 0 9 per cent sodium chloride) gives better results than ordinary saline, which passes out of the vessels too quickly Glucose 5 per cent, in normal saline is very generally employed The body-heat is preserved by having the table warmed by limiting exposure as far as possible, and by giving warmed vapour The Trendelenburg position is a great help in avoiding shock during long abdominal operations Whenever shock is present much care is needed in altering the position of the patient Dangerous effects can easily be induced by suddenly raising the trunk, or the head and neck or even by too abrupt rolling

Restorative measures in collapse during anæsthesia —There is no need to dwell upon the ordinary steps to be taken at once in cases of failure of respiration Withdrawal of the anæsthetic, lowering the head drawing forward the tongue and securing a free air-way, followed by rhythmical compression of the chest and, if necessary, systematic artificial respiration must be employed at once Recent work has, however extended our knowledge of the possibilities of resuscitating those patients in whom there is no reaction to these first measures *Cardiac massage* has been put upon a firmer basis as a successful measure when all else has failed It is based upon physiological experiments beginning with those of Schiff in 1874, who proved that it was possible to re establish cardiac pulsation and respiratory move

ments even up to $11\frac{1}{2}$ minutes after the heart had stopped in animals killed by overdoses of chloroform Later workers resuscitated dogs after they had been asphyxiated or rendered pulseless by electricity The first reported complete success in the human subject appears to be that of Lane in 1902 It is supposed that the cardiac massage acts by restoring circulation through the coronary arteries ' The aspirating effect of the recoil of the heart-wall, after compression in all probability determines a flow of blood from the large veins into the auricles, and so into the ventricles (Norbury) From the ventricles it is squeezed into the coronary arteries and it has been proved that normal saline injected into the coronary arteries stimulates the heart itself and will restore the beat even in animals with brain and cord destroyed Levy holds that massage does not provide a mechanical stimulus to recovery but that it restores the fibrillating ventricles to that condition in which they can exert their natural tendency to recovery, and maintains this condition until recovery takes place

Cardiac massage cannot be effectively performed without opening the abdomen, except in young children When the abdomen is open the massage may be performed either subdiaphragmatically or after incising the diaphragm (transdiaphragmatic route) The former is quicker The surgeon passes his hand between the diaphragm and the left lobe of the liver The heart is defined and pressed against the thoracic wall, counter-pressure being maintained with the other hand against the left ribs or else the heart is kneaded through the diaphragm by the closed fist Whatever method is employed artificial respiration should be carried on at the same time and may have to be continued after the heart has resumed its beat

Henschen describes a case in which the heart of a man of 82 was revived by 1 5 c c epinephrin injected through the 4th left interspace Recently it has been shown that stimulation of the heart by insertion of a needle preferably into the wall of the right auricle, is an effective means of restarting its action Probably it is a matter of indifference what, if any, drug is injected it is the prick of the needle which provides the needed stimulation The third right interspace half an inch from the sternum is the place where the needle—a slightly curved one—should be inserted

It is probably useless to try to restore the heart s action more than thirteen minutes after respiration has ceased Nor should operations for massage of the heart be started until at least five minutes have been spent on artificial respiration and allied measures

CHAPTER II

CONSERVATIVE TREATMENT IN SURGICAL TUBERCULOSIS

By SIR HENRY GAUVAIN

INTRODUCTORY

OPERATIONS in surgical tuberculosis should rarely be considered until the possibilities of conservative treatment have been explored It is therefore logical to include non operative measures in a work of this description Moreover conservative methods need to be used more and more in connection with operative treatment

Open air and sunlight are equally valuable in radical and in con servative treatment Their value is unstintingly recognized by those of conservative tendencies but it is much to be deplored that they are not more generally employed in ordinary hospital practice No modern hospital should be erected without ample balcony accommodation The recent invention of the heliodon gives the modern hospital architect the opportunity of so constructing his hospital that the utmost possible advantage may be taken of available sunshine

For those who live in towns more advantage should be taken of gardens public parks or even back yards and flat roofs for open air treatment The importance of general treatment as a means of raising resistance to the tubercle bacillus in cases in which some surgical intervention is indicated cannot be too strongly stressed and I plead for a greater recognition of its value

By conservative treatment of surgical tuberculosis is meant the adoption of all measures which tend to improve the patient s general health increase the powers of resistance to tuberculous disease and preserve or restore the part or parts attacked—in contradistinction to radical treatment which aims at the cure of the disease by the removal of the focal lesion

While such a definition does not necessarily exclude surgical inter ference it obviously does involve the use of very active numerous and sometimes complicated methods of treatment calculated to secure the arrest of the disease and at the same time reduce to the utter most disablement or deformity induced by specific lesions Pure surgery from being the one treatment is relegated to an inferior but at times still useful position as a possible aid to cure or amelioration under certain conditions

It is important to note that this conception of treatment differs

widely from what was formerly understood by conservatism, which, at one time, was thought to mean merely avoidance of operative interference, and which offered little in the place of surgical intervention Indeed, conservative treatment was almost synonymous with absence of treatment, or at most connoted the convalescent treatment applicable in any cripple home, no matter how ill equipped or indifferently staffed Conservatism, as originally understood, had its beginnings in pre antiseptic days, when surgical interference was almost futile

New principles in treatment became indicated with increasing knowledge of the pathology of tuberculous lesions and the belief that they were the result of a local infection or disease and subsequent excentric destruction of tissues by tuberculous elements advancing much as does a neoplasm From this new " tuberculome ' conception evolved, logically, a radical surgical treatment which, supported by the recent discovery of antiseptics, consisted in the total removal of tuberculous tissues This practice, possible and efficacious with small tuberculous foci, exposed the patient to serious risk when applied to extensive, longstanding lesions Moreover, while it was hardly ever possible completely to remove the infected tissues, the method, by the extensive mutilations which it involved, produced deplorable orthopædic results In particular, systematic resection of the hip joint which was practised in every case of abscess-formation, left the patients who recovered sadly crippled In spinal caries the removal of all tuberculous material was rarely possible, and extensive surgical interference with such lesions was disastrous in the extreme

These extensive operations were followed by both a high immediate and a high subsequent mortality They created large areas of absorption which exposed the patients to grave dangers of fresh inoculation of tuberculous or other organisms , and general dissemination, meningeal lesions or lardaceous disease often followed Clinical considerations gradually led to their abandonment, and there ensued a less daring and less radical surgical period which is now gradually being superseded by even more restricted direct operative interference

This limited surgical practice confines itself largely to an attack on the abscess abandoning, as a rule, attempts at the complete removal of the more extensive bony lesions Essentially, it consists in curetting or excising the abscess cavity, or even merely incising and evacuating the contained pus, under the most rigorous antiseptic precautions The incision is then sutured, when possible without drainage Indeed, in bone and joint disease, direct attack by operation, other than excision or erasion of small tuberculous foci, is to-day very largely confined to the evacuation of complicating abscesses Excision of large actively tuberculous joints is performed more and more rarely, except for tuberculous disease of the knee joint in adults Amputation of limbs is almost entirely confined to those cases in which severe secondary sepsis endangers life

Many surgeons had already arrived at this stage a decade or more ago, as a result of bitter clinical experience In the preface to the

second edition of his work on Tuberculous Diseases of the Bones and Joints (1911) Sir Watson Cheyne wrote —

> There is no question that operative interference is very much less frequently employed at present than it was at the time when the first edition was published Since that *time however experience* has been accumulating and has shown that with careful hygienic and local treatment the outlook of tuberculosis especially of the forms met with by the surgeon is more favourable than was at that time thought and the frequency of operations especially at the early period of the disease and in the absence of suppuration has been steadily diminishing Indeed the pendulum is tending to swing rather too far in the conservative direction

The first part of this quotation still holds good, the last sentence now needs revision Careful hygiene and local treatment have become even more potent factors in obtaining a cure and are now applied with ever *increasing intelligent care* and in *addition* other aids to cure—numerous and in certain circumstances of immense value—have been introduced their potentialities explored and their value more and more realized and appreciated Conservative treatment no longer means merely the application of simple rules of hygiene and imperfect local treatment In the light of the definition already given conservative treatment has assumed an importance and a value which a generation ago was almost incomprehensible increasing research knowledge and experience have placed the principles of conservatism on an ever surer and more stable basis

It is important to realize that a bone or joint lesion is rarely the primary focus of infection The organism has already obtained lodgment in its host Subsequently conditions being favourable it establishes itself and produces pathological changes in various organs The resulting lesion is a local inflammation *in a tuberculous patient* and not merely a local inflammation This fact is of great importance, it increases at once our powers and our responsibilities The excision of a tuberculous lesion a logical procedure under the tuberculomic theory is as I have said no longer necessarily sufficient in the light of this new knowledge And the more tuberculous disease is investigated the greater becomes the evidence that it is a *general* infection With increasing skill and improving technique the bacteriologist is now able to isolate the bacillus not only from the local lesion but sometimes even from the circulating blood itself The cause of the disease being known the question at once arises whether the bacillus may not be directly slain in the tissues it infects without danger to its host and this has suggested methods of treatment of great promise but hitherto of small fulfilment Nevertheless vaccines and chemotherapy are methods theoretically at any rate full of possibilities and even now in certain circumstances they may be usefully employed as adjuncts in conservative treatment

So much interest has been focused on the seed the tubercle bacillus that too little attention has been paid to the soil in which it is sown—the patient Different races different individuals and even different

tissues in the same individual show widely differing powers of resistance to the bacillus Moreover under differing conditions the resistance of the same individual varies enormously Toxæmia from various causes—exposure trauma bad heredity unfavourable social conditions —all lower resisting power But while the individual resistance may be thus lowered so it may also be raised and this is one of the most powerful means at the disposal of the conservative surgeon in preventing or eradicating tuberculous disease

By good hygienic conditions simple and suitable diet life in the open air and under the tonic and bactericidal influence of the sun the patient s immunity may be so reinforced that he may achieve high resistance to infection and even overcome the disease himself This fact is becoming increasingly recognized and well planned and co ordinated methods of prevention are assuming a continually more important place and are urgently indicated where bad heredity or unfavourable social conditions render an individual especially liable to infection

While the discovery of the tubercle bacillus and increasing interest in problems of immunity have contributed largely to the importance of conservative treatment in surgical tuberculosis the gravity of sinus formation with its risk of secondary infection has rendered even more urgently and vitally necessary the adoption of methods which will reduce to a minimum the risk of so serious a complication It is here that conservative treatment has achieved its most brilliant success Closed a tuberculous abscess is comparatively harmless Open there is the great danger of secondary septic infection A sinus is almost always followed by septic infection both of the sinus and of the focus of disease from which it originates Profuse suppuration and fever exhaust the patient amyloid disease or general dissemination is likely to follow and not only is the period of incapacity unduly lengthened and recovery more difficult but death itself is not uncommon It has been estimated that 75 per cent of cases of spinal caries with septic sinuses die as the direct result of secondary infection The direct mortality in spinal caries without added sepsis should not exceed 4 per cent and even this low figure is diminishing

For convenience in description we may consider conservative treatment under the following headings General Local and Adjuvant

GENERAL TREATMENT

This includes all those methods calculated to raise the resistance of the patient such as climate hygiene diet drugs discipline education or suitable occupation and treatment in institutions specially designed equipped and staffed and established in suitable localities

Rest —It may seem unnecessary to emphasize the importance of rest but adequate rest and wholesome sleep are not always prescribed as insistently as they should be Rest in acute cases should be strictly enforced and should comprise not only recumbency but also immobili

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zation of the part affected, the immobilization being especially designed for the special needs of the particular lesion, and the prevention or correction of deformity Natural sleep is also very important and is promoted by life in the open air, absence of irritating and unnecessary noise, comfortable and congenial surroundings, freedom from anxiety and pain, and suitable diet

Climate and locality.—A sunny is to be preferred to a comparatively sunless climate Clear, bracing air, with absence of smoke or fogs, is of great importance The patient is therefore best removed from smoky industrial districts Marsh lands, river valleys, and lake districts should be avoided There should be only moderate rainfall, for as much time as possible should be spent in the open air In England, inland treatment is best obtainable on the chalky North or South Downs at reasonable elevation The rainfall is moderate and cleans the air, the chalk at once absorbs all moisture, the elevation is sufficient to improve muscular tone and stimulate the appetite, there is abundant sunshine, and it is possible that the hard drinking-water is not without therapeutic value Wide, wind-swept spaces are reflected by a healthy muscular tone not obtainable in the stuffy confines of a town or enclosed valley Speaking generally my experience is wholly in favour of inland treatment in suitable localities for acute cases or for young children Marine treatment may be preferable for older patients when the disease is not so active, particularly in chronic cases with sinus formation For children under five, it is generally best to avoid the sea altogether

For marine treatment certain desiderata are indispensable for the best results A flat littoral extensive sandy beach, and wide excursion of tide are essentials Along the beach the prevailing wind becomes charged with substances which we feel to be helpful even if we cannot altogether define their nature The patient should reside as close to the sea as can be arranged, both for easy access and for the sake of the benefit from reflected sunlight Low rainfall, bracing but equable climate clear atmosphere with absence of mist and smoke, remoteness from towns, unrestricted use of beach and sea, and protection from cold winds are all factors of primary importance in the cure On the south coast of England, Hayling Island possesses these desiderata to a marked degree, and hence has been selected for the marine branch of the Treloar Cripples Hospital

In Switzerland, Leysin and Montana are admirable examples of localities suited for the Alpine treatment of surgical tuberculosis, when mountain treatment is specially indicated The advantages are low atmospheric pressure, low rainfall and dryness of atmosphere, infrequency of winds, inconsiderable fog, prolonged duration of sunshine of high actinic value, augmented in winter by reflection from the snow, intensity of heat rays, and pure cool air of high radio-activity It is doubtful, however, if these advantages sufficiently compensate for an expensive and fatiguing journey to a remote district in a foreign country.

In certain cases it will be found of real benefit to vary treatment between inland and marine stations for change of air and scene, especially when heliotherapy and balneotherapy are indicated For those able to cross the sea to a milder climate where heliotherapy and sea-bathing can be longer enjoyed than in England, the Channel Islands possess peculiar advantages with the additional inducement of English rule and low cost of living

Occupation.—A point of importance which has not received the attention it deserves is the occupation of the patient while under treatment Children should be educated adolescents trained, and adults congenially employed In chronic disease of long standing this is a matter which has marked influence on the psychology and future of the patient A normal healthy well cared for suitably occupied patient is a happy patient He is able to give full play to natural healthy mental and physical activities The monotony of long enforced recumbency and immobilization is alleviated Attention to this matter is reflected in the patient s responsiveness to treatment and materially assists in cure

Tuberculin—Tuberculin in the treatment of surgical tuberculosis has been advocated by many abandoned by most and continued by few I have tried many types of tuberculin as advised by enthusiasts in numerous cases The results were uniformly unconvincing Eventually with the generous assistance of one of the most distinguished exponents of this form of treatment a number of cases with controls were subjected to this treatment with the most careful precautions for a prolonged period The results were negligible and I remain unconvinced Need more be said?

LOCAL TREATMENT

Careful local treatment is supremely important for the cure of the local lesion, the prevention or correction of deformity and the management of complications such as abscesses or sinuses It necessitates minute attention to detail and is largely orthopædic with the added limitation that the patient is tuberculous Forcible or rough manipulation must always be avoided as that would facilitate further local spread or general dissemination

In acute disease the essentials are rest, frequently involving recumbency, with efficient immobilization of the lesion, and the simultaneous adoption of measures designed to prevent or correct deformity Deformity in joint tuberculosis is largely the result of spasm induced in neighbouring muscles, and can therefore be best countered by gradual traction on the muscles involved while the lesion itself is kept immobilized Recumbency is generally indicated in acute, commencing or progressing lesions, but is often not indispensable in the chronic or subacute stage Here, however, immobilization of the lesion is still desirable to assist repair or prevent recurrence or increase of deformity Finally, during convalescence, protection or support is generally

indicated and is best provided by light accurately fitting removable splints which may be discarded while the patient is lying down The stages in which varying local means of immobilization or support are indicated are subject to variations depending upon numerous factors such as the site and extent of the lesion the virulence of the infection individual power of resistance and repair age of patient presence or absence of other lesions and complications and conditions under which treatment is being conducted

Allusion should be here made to fixation of tuberculous joint lesions by operative methods These operations present a great advance in treatment and are conservative in nature as they are not designed in any way to attack the lesion but merely to immobilize it more effectively than is possible by external splintage In spinal caries the operation of bone grafting as advised by Albee bone fusing as recommended by Hibbs or modifications of these are becoming exceedingly popular and are better understood than they used to be Arthrodeses are of great value especially in tuberculous disease of the hip-joint for fixing affected joints and thus reducing the risk of subsequent deformity if merely fibrous ankylosis is achieved after treatment of the acute disease

SURGICAL TREATMENT

I will sum up briefly the indications for operative interference in surgical tuberculosis

Where there is a purely local infection (e g a tuberculous finger following direct infection) amputation or excision is undoubtedly wise it shortens treatment and reduces risk of dissemination In tuberculous disease of the spine operation is indicated to relieve pressure symptoms on the spinal cord if reasonable conservative treatment has failed Here *costo transversectomy* is usually the operation of choice but laminectomy may be sufficient In patients of poor physique and feeble musculature especially in disease affecting the thoracic vertebræ bone grafting as advised by Albee is indicated when the disease is approaching quiescence This is essentially a conservative operation and is designed to reduce the risk of subsequent deformity or to hasten consolidation and shorten treatment It is never advisable in early or in progressive disease

Arthrodesis preferably of the extra articular type is indicated in tuberculous diseases of the hip joint when unstable fibrous union occurs and there is a definite tendency to adduction deformity In acute or progressive disease it is not called for It should be regarded as a conservative measure to prevent deformity but is not a treatment which will arrest the spread of active disease In tuberculous disease of the knee joint conservative treatment should always be practised in growing children and operative treatment is not indicated In adults however with no tuberculous lesions elsewhere early excision is the treatment of choice after a preliminary period (say three months) of fixation under suitable open air and hygienic conditions Con

servative treatment is here too lengthy and too uncertain in its final results Besides, in an adult, time is a very precious factor, and it is better to have a stiff but safe leg for the remainder of life than to have an uncertain though movable knee-joint which may show recurrence at any time

More radical measures are indicated where added sepsis and secondary infection, with the possibility of amyloid disease suggest that complete extirpation of the lesion is indicated to save life Bony foci in the neighbourhood of, but not involving, joints may sometimes be excised with benefit

Tuberculous Abscesses of Bony Origin

Of complications occurring in bone and joint tuberculosis and demanding local treatment the most important are abscess and sinus formation Evacuation of a tuberculous abscess by incision should, wherever possible, be avoided Occasionally, under favourable conditions a tuberculous abscess will absorb or calcify In certain inaccessible situations, such as the posterior mediastinum when its presence causes no untoward symptoms the patient s best interests are served by avoiding surgical interference and every endeavour should be made to promote absorption or calcification In small abscesses secondary to insignificant but accessible local lesions, both abscess and causative lesion may at times be advantageously excised with aseptic precautions In the vast majority of cases, however, abscesses should be evacuated by aspiration with due regard to correct technique

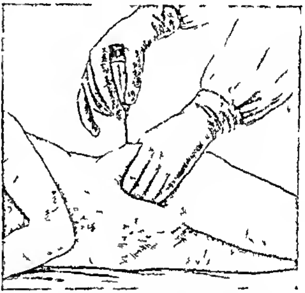

Fig 6 —Aspiration of psoas abscess

A modified Record syringe of 10 20 c c capacity is employed With such a syringe are supplied a trocar, cannula and blunt-pointed probe The calibre of the cannula should, as a rule, be 1 5-2 mm

The operation is as a rule comparatively simple Anæsthetics are rarely required, except in very young or nervous subjects The skin may be frozen if desired, but even this is unnecessary The limits of the abscess cavity are established with care and its relations with neighbouring organs defined

Much depends upon the point selected for the insertion of the cannula

with the enclosed trocar The trocar should traverse healthy skin, and its point of entry should be as remote from the abscess as is reasonably possible Care should be taken to select for insertion a spot whither the abscess is not likely to extend Thus, in aspirating a *psoas abscess*, the super adjacent skin should be gently pressed with a sliding motion inwards with the left hand The limits of the abscess are defined by the left hand the fingers pushing aside and guarding peritoneum and viscera (Fig 6), the thumb steadies the hand by pressing on the iliac bone The trocar penetrates the skin by a sharp movement at a point just external to the anterior superior iliac spine, then, by a gradual deliberate movement, the abscess is entered Immediately there is an exceedingly characteristic sensation of freedom and lack of resistance Having entered well within the cavity, the trocar is withdrawn, the cannula remaining Pus often escapes immediately, but this depends on the tension inside the abscess and the density of the fluid When it ceases to flow by its own pressure it is further withdrawn by gentle aspiration When no more pus can be thus obtained, the syringe is detached, and the cannula gently cleared with the probe If no more pus can be withdrawn, the abscess is compressed again with the left hand, the abscess cavity gently explored with probe and cannula, and aspiration repeated An experienced surgeon can often, with this procedure, withdraw a considerable quantity of pus the presence of which was hardly suspected

To complete the aspiration, manœuvres suggested by experience are carefully attempted Thus, more pus may often be withdrawn by altering the direction of the cannula, or elevating or depressing its orifice *Exploratory movements should never be attempted with the syringe attached*, but only when the cannula is occupied by its probe With patience, care, and skill, an abscess cavity may in this way be completely emptied unless much caseous material is present Finally, when no more pus can be obtained, the cannula, with the probe within it, *is gently withdrawn, or it may be withdrawn while still aspirating* the empty abscess cavity, thus preventing the deposition of any purulent material in the track of the needle

When the cannula is removed the skin displaced towards the umbilicus slips back and the original point of entry is well external and posterior to the *anterior superior iliac* spine *Thus a valvular*, well sealed track has been made, which readily heals and prevents pus from escaping should it re-form The puncture is gently squeezed wiped with a little ether, and sealed with a small pad of gauze soaked in collodion

The principles adopted *in aspirating* a *psoas* abscess *apply* to abscesses elsewhere An abscess should never be aspirated directly over the swelling but always at some distance away through healthy tissue, and the track of the needle should be, if possible valvular Tissues which might possibly be invaded by the abscess, if it refills and extends should always be avoided *Abscesses in connection* with the *hip-joint* other than acetabular or supratrochanteric, tend to track down the

limb, the needle should therefore be inserted above their point of origin, or at any rate well to one side

A single aspiration may permanently empty an abscess, but this is unusual The causative lesion remains and, if it is active, the cycle of evolution of the abscess is repeated Aspiration may therefore be required several times Usually, however, the abscess tends to shrink, and less pus is removed at successive aspirations The quality of the discharge alters It often becomes more sanious less purulent and frequently more fluid This is of good omen and an indication of approaching cure Moreover, as the abscess diminishes in size its walls often become denser and more sclerosed eventually a diminishing fibrous mass replaces the old abscess cavity and seals off effectively its causal lesion, towards which it shrinks and eventually in turn disappears

This desirable sequence of events though usual is not invariable At times, in spite of repeated aspirations the abscess continues to increase in size spreading ever nearer the surface involving adjacent tissues, and, unless care be taken eventually ulcerating through the skin In such cases the use of so called modifying fluids may be of value Of these the most generally useful and commonly employed is iodoform in suspension or solution the latter to be preferred I generally use two solutions one oily, the second etheric The effect of the commoner modifying fluids is to produce an aseptic inflammatory reaction in the abscess cavity The abscess walls become engorged with blood, lymph and polymorphonuclear leucocytes pass into the cavity, even red blood corpuscles may appear if the reaction is considerable Caseous pus tends to become more fluid This digestion of the pus is due to the liberation of a proteolytic ferment analogous to the tryptic ferment of the pancreas, which has the power of digesting coagulated albumins and transforming them into peptones and amino acids The ferment is liberated in the destruction of the polymorphonuclear leucocytes which invade the abscess after the injection of modifying fluids It does not occur in the ordinary tuberculous abscess because of the absence of polymorphonuclears in it Subsequently the abscess-walls become more sclerosed and their retraction is hastened when the fluid contents are evacuated by aspiration

The oily iodoform solution recommended is the following —

℞	Iodoform	grm v
	Ether	grm x
	Guaiacol } Creosote }	aa grm ij
	Sterilized olive oil	100 c c

Inject from 5 to 10 or even 20 c c, repeating the injections if necessary The smaller dose should be tried first, as some individuals show idiosyncrasy to iodoform This mixture is especially useful when the tissues round the abscess tend to become invaded, the abscess increases rapidly in size, and the pus is thick without being very caseous

In the absence of caseous pus, but when the cavity rapidly refills

with thin fluid and the walls show no signs of becoming denser by the formation of fibrous tissue, injections of 5 to 10 c c of 10 per cent iodoform dissolved in sulphuric ether are recommended This, after early reaction causing increased formation of fluid, has a drying and sclerosing effect The abscess-walls become denser and harder, and retract more quickly The ether should all be allowed to escape through the cannula before it is withdrawn freshly precipitated iodoform in the form of a fine powder being left behind on the abscess walls

Whenever the abscess contains caseous pus which cannot be with drawn, cautious injection of a solution containing thymol 1 part, camphor 2 parts and sulphuric ether 8 parts, in doses of 2 3 c c, may be employed This is much more active than the iodoform solutions, and may, by the irritation caused, increase the activity of the bony lesion It is, however, at times exceedingly useful in liquefying caseous pus, which often becomes flaky, fluid and sanious If the reaction provoked is excessive, lotio plumbi should be applied on lint

Many other modifying fluids have been advocated, but the three mentioned are sufficient for the great majority of abscesses

Tuberculous Sinuses

Sinuses secondary to abscess formation are common complications in bone and joint tuberculous lesions, and are often particularly difficult to treat After efficient conservative treatment, they should rarely, if ever, arise They usually occur in neglected cases in which an abscess has opened spontaneously, or after operative treatment when primary union has not occurred, or, more commonly, when a healed scar has broken down Every endeavour, by vigorous aseptic technique, should be made to avoid their secondary infection but even with the greatest care this sometimes occurs Immediately secondary infection has taken place, if it is accompanied by constitutional disturbance, autogenous vaccine treatment should be pressed or effective chemotherapeutic drugs, such as Prontosil should be exhibited if hæmolytic streptococci are present Simultaneously, free drainage and fomentations are desirable Such measures are, however, only effective in recent cases of infection

In chronic sinuses, sequestra should be gently removed, if accessible without undue laceration and consequent risk of added infection Scraping of sinuses is usually best avoided but free drainage should be ensured Alteration of posture to meet this need is often helpful and sometimes benefit is obtained by ambulatory treatment with suitable safeguards As a rule, dry are preferable to moist dressings In old chronic sinuses where the primary lesion is healed, injection of Beck s bismuth paste or Bipp the former by preference, is often remarkably successful

Heliotherapy, balneotherapy (*see* below), and X-ray treatment, singly or in combination, are often of the greatest possible assistance Cases most suitable for X ray treatment are old thick walled sinuses in thin subjects Dosage is important, the cross fire principle should be used where feasible and the mouth of the sinus should be shielded after the

first or second direct application. Supple, non-cheloidal scars are the rule after this treatment.

ADJUVANT TREATMENT

By adjuvant treatment I mean the additional methods which may be used during the course of the disease and which, when properly selected and employed, will assist in and accelerate the cure. Under certain conditions one or more alone may effect cure. Thus, Finsen light alone may cure a patch of lupus in a patient who is carrying on his normal life. In the severer forms of surgical tuberculosis, however, these aids to cure, even when combined, are rarely sufficient in themselves. The terms " sun cure," or " X-ray cure," as applied to surgical tuberculosis, are therefore open to objection, and, in my opinion, should not be employed without qualification. The best results will be secured by the clinician who supplements the regular, recognized, logical methods of general and local treatment by the judicious use of these aids to cure as and when indicated, singly or in combination, throughout treatment or at certain periods of treatment.

These adjuvant methods have largely increased in relative importance, popularity and scope of application in recent years. They represent the most recent and perhaps the most interesting advances in the non-operative treatment of surgical tuberculosis. Among them are heliotherapy, balneotherapy, chemotherapy, vaccine treatment, and the therapeutic use of X-rays and other electrical agents.

Heliotherapy

Of all adjuvants to cure, sun-treatment (Fig. 7) has chiefly come into prominence in recent years. The extravagant claims made for this method may be discounted; nevertheless, heliotherapy, skilfully utilized in suitable cases, is of substantial assistance. The action of sunlight may be conveniently considered as (1) local or direct; (2) remote or indirect. The value of sunlight has been ascribed to the ultra-violet rays in the solar spectrum, though these have little penetrative power, and it is probable that light of all wave-lengths is of value. The reds and infra-reds have the greatest penetrative capacity.

The *local or direct* action of sunlight is confined to superficial lesions, which are benefited by the bactericidal action of sunlight combined with the favourable inflammatory response which carefully-graduated exposure elicits. It is especially valuable in such superficial lesions as lupus vulgaris, tuberculous ulcerations, pustules, and the like.

The *remote or indirect* action is different. It appears to be definitely associated with the formation of pigment in the skin. At any rate, only in well-pigmented patients can considerable exposure be attempted and much benefit obtained. Pigment has a protecting rôle, and pigmented patients are able to tolerate a lengthy exposure which would be dangerous or fatal in its absence. Pigment in the skin is the result of exposure to ultra-violet radiation plus some property possessed by and peculiar to each individual. The existence of an

enzyme in the skin responsive to light may be assumed as the cause of pigment formation Sandy and red haired patients often possess little pigmenting power but absence of pigmenting power may also be met in brunettes and even in the black races In cases which do not pigment the production of facial freckles is not uncommon Freckling is of no value and though skin pigmentation and freckling may occasionally occur in the same patient not infrequently the freckler is largely deficient in pigmenting power

Whether pigment formed in the skin has more than a protective value is not yet definitely established It has been suggested that pigment may have a transforming power translating light waves of short wavelength and little penetrating power into long waves of

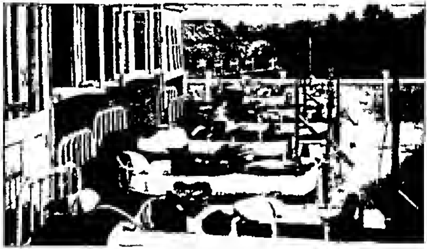

Fig 7—Patients undergoing heliotherapy on a solarium at Alton

great penetrative power It has also been suggested that the physical energy of sunlight is transformed into chemical energy through the agency of the pigment formed in the skin Such theories are nothing but surmise and rest on no certain basis of fact Leonard Hill and others however have recently demonstrated that ultra violet radiation has the power of temporarily raising hæmobactericidal power in the rabbit to a very marked degree This effect is only produced *via* the tissues as drawn blood directly irradiated does not exhibit it Carl Sonne advances the theory that the curative effect of the universal light bath is due to the capacity of the luminous rays during the light bath to heat a very essential portion of the aggregate blood volume of the organism to a temperature possibly exceeding the highest ever measured fever temperature without causing the body temperature to rise to any appreciable degree and he produces sound evidence for this statement Much of the interest aroused in heliotherapy is the result of the admirable clinical work done by Rollier whose insistent advocacy fortified by the excellent results of his treatment has inspired many to practise insolation according to the routine he has successfully

adopted A temperate climate is the best for insolation, which can be perfectly well practised in England

Stress should be laid on the psychological value of properly applied insolation The natural-light bath stimulates enlivens, exhilarates if too prolonged, it intoxicates and exhausts It is therefore of supreme importance to graduate the time of exposure Only thus utilized is heliotherapy beneficial The advantage of good hygiene, open air life and sensible sun treatment is now universally recognized, but many workers still fail to appreciate the *contra indications* to open-air and sunlight Open-air stimulates metabolism Exposure to light to some extent resembles a shock stimulus For beneficial effects alternations of light and shade are preferable to continuous light, and darkness is, therefore, as essential as light There are diurnal and seasonal as well as individual variations in response to the stimulus of light It is more effective in the morning and in the spring and early summer than at other periods Prolonged and continuous exposure to light produces either ineffective tolerance or profound exhaustion No exact rules can safely be laid down for time of exposure, which should vary with the character and intensity of the light and individual power of response Experience and observation should be the guide Heliotherapy must be regarded as an art rather than as a science Both sun and air treatment demand individual response In the very ill, debilitated patient, the elderly, the cachectic, the non-pigmenter, and the toxic, there is often a difficulty in safely obtaining that response The call on the patient is too severe, he is unable to effect the favourable reaction Such patients should be spared the effort They should be nursed in warmed, well ventilated wards and not exposed to sunlight Direct light and open air treatment will only lead to disaster Happily most sun-sensitive subjects recognize this and themselves realize that they are intolerant to insolation

Of local lesions, *sinuses* are often favourably influenced, there is increased discharge which becomes more serous and less purulent, and eventually the sinuses may heal, leaving supple, non-cheloidal scars *Sequestra*, especially from the small bones, are sometimes spontaneously extruded The analgesic effect of insolation is pronounced and is of especial value in *intestinal* and in *genito urinary tuberculosis*, both of which are favourably influenced Tuberculous *adenitis* frequently reacts favourably, particularly if the glands are simply inflamed and pus has not yet formed Overexposure must be guarded against as pus formation may ensue, though sometimes this may be intentionally encouraged In "*closed*" *bone-and-joint tuberculosis* patients who respond well to heliotherapy seem to improve more rapidly and repair more completely A stimulus appears to be applied to the cure, the patient is energized and exhilarated, and improvement accelerated As the local lesions improve there is impressive general improvement, and especially enhanced muscular tone

Pigmenting power appears to be, to some extent a measure of resisting power Failure to induce pigmentation is not infrequently associated

with latent tuberculosis or profound tuberculous toxæmia Subsequent development and successful treatment of a hitherto unsuspected lesion are frequently associated with acquisition of pigmenting power, which then synchronizes with rapid improvement Failure or success in developing pigment, therefore often acquires valuable prognostic significance Amongst benefits ascribed to successful insolation may be cited increased resistance increased metabolic activity, and increased power of absorption and elimination the discharge of toxic products being hastened The skin's functions are partly in abeyance when it is enveloped in clothes and this heightened cutaneous activity is of value to the subject insolated The respiration rate is slowed, but amplitude is increased and oxygenation improved Blood pressure is reduced The blood itself is modified, the red cells are more numerous and contain more hæmoglobin and leucocytosis is common

Some of these changes particularly the increased metabolic activity, may be due to exposure to cold air, but exposure to air is facilitated in the bronzed subject clad and protected in his own pigment Leonard Hill and Argyll Campbell working at Alton and elsewhere, attach great importance to the cooling power of the air on the nude bodies of exposed patients, and advance sound arguments for ascribing increased metabolic activity to this factor The clinical improvement noted after exposure can, however, only in part be ascribed to increased metabolism Aerotherapy without heliotherapy is deprived of much of its value, and patients unsuitable for insolation do not benefit by mere exposure to the air even to approximately the same extent as do patients capable of receiving both sun and air treatment I incline to the opinion that too sudden or too extreme increase of metabolic activity is harmful that the metabolism of the patient should be raised gradually and so maintained, that there is an optimum metabolism which should not if possible, be exceeded and that this optimum is a varying one depending on the individual the age, and the nature of the lesions

In patients suffering from surgical tuberculosis heliotherapy is contra indicated for its remote effects in non pigmenters, in amyloid disease with any considerable pyrexia and when associated with certain complications either pulmonary or non tuberculous

Technique of general sun-treatment—Patients should be acclimatized before insolation commences exposure should be gradual and progressive excessive reactions should be avoided, the patient should never be too hot nor too cold and the head should always be protected by a canopy or sun hat The amount of exposure patients can tolerate varies within wide limits After the sun bath the patient should feel exhilarated and insolation should never proceed to the degree of causing either blistering of the skin or exhaustion The legs below the knees should first be exposed for short periods e g five minutes hourly, the length of exposure and the amount of surface exposed being increased slowly each day if climatic conditions permit,

until total exposure is possible Under favourable conditions there should be at least a fortnight of progressive increase of surface before complete exposure Insolation of red haired, freckled, thin skinned or elderly patients must be attempted with extreme caution

General pigmentation should be aimed at and should be maintained and intensified as conditions permit Under conditions favourable for insolation, successful results will largely depend on skilful and progressive exposure The aim is invigorating reaction accompanied by a sense of well being, and acquired without effort or concentration It will then accelerate and consolidate the cure reduce the length of treatment required, greatly improve the patient s general health, increase his power of resistance and directly benefit the majority of local tuberculous lesions

In tropical regions insolation should be most carefully administered as other problems there present themselves associated with excessive heat and quality of sunlight Artificial light and avoidance of direct sunlight is often to be preferred abroad

Artificial Light Treatment

This is being increasingly used especially in localities deficient in natural sunlight and in the winter months No modern hospital designed for the special treatment of surgical tuberculosis can be considered satisfactorily equipped unless provided with a well planned and organized artificial light department, where both local and general treatment is undertaken The former is principally concerned with the treatment of superficial cutaneous lesions such as lupus vulgaris, or of sinuses secondary to deeper lesions For lupus vulgaris, the Finsen lamp, or one of its modifications the Finsen Reyn or Finsen-Lomholt lamp is especially indicated These lamps are complicated and their use requires special training but they give results immeasurably superior to those of other lamps in this particular condition The general light-bath should be employed concurrently

The Kromayer a water-cooled mercury-vapour lamp with suitable quartz applicators may also be employed for lupus vulgaris but it is not so effective as the Finsen lamps Tungsten arc or Kromayer lamps are of great value for the treatment of sinuses or patches of scrofuloderma

For general treatment, carbon arc lamps either the short flamed variety as used at the Finsen Institute, or the long flamed arcs, with or without cored or impregnated carbons, as more commonly used in England, are of value Exposures should usually be given on alternate days, the time varying with the type of lamp used and the individual reaction Lamps which emit much ultra violet radiation are not more effective but have the advantage of shorter exposure time Where time is not of extreme importance as in the treatment of children in institutions, the short flamed, more slowly-acting Finsen arcs are to be preferred, the pigmentation they produce is very like that of natural sunlight Where time is important powerful, long flamed arc lamps are

more convenient Air cooled mercury vapour lamps in quartz containers are simple but are not so useful in the treatment of surgical tuberculosis

General light treatment, either natural or artificial, may be regarded as a tonic and shock treatment Continuous exhibition of such treatment is, therefore, both unnecessary and inadvisable, and the best results are obtained by discontinuing treatment when optimum benefits have been obtained The periods of treatment will show wide variations with different individuals and no accurate rules can be laid down

Balneotherapy

Among natural aids to cure, suitably managed sea-bathing takes a high place It intensifies and supplements heliotherapy and aerotherapy, with which, in the open sea and on a sunny coast, it is naturally associated Properly timed sea-bathing, followed by brisk towelling, a hot drink to stimulate reaction, and a short sun-bath induces, in suitably selected subjects, a sense of exhilaration and well being which nothing else can effect It immensely increases the efficacy of the simple sun-bath Moreover, the actinic value of sunlight is greatly enhanced by the sea which reflects the ultra violet and luminous rays but absorbs the red and infra reds Sea bathing rapidly increases metabolism, according to Leonard Hill, the metabolic activity of a swimmer may be ten times as great as the normal, or more Immersion alone, or even paddling, results in a rapid increase of metabolism The increase may be graduated with nicety according to the needs of the patient by spraying, paddling, or complete immersion, short or lengthy, as indicated in individual cases Immersion should never be so prolonged that rapid and healthy reaction is not induced Immersion is associated with deep gasping respiration which effectually expands the lungs, improves oxygenation of the tissues, assists in the expulsion of waste products, and promotes diuresis The circulation is profoundly modified The first chilling effect causes contraction of the superficial vessels, followed by their dilatation when reaction occurs All parts of the body are in phases flushed by increased passage of blood and lymph, oxygenation is increased, accompanied by greater tissue change and heat production, and these effects are apparent in diseased as well as healthy tissues with obvious therapeutic benefit

Sinuses secrete more, the discharge being less purulent and more serous, and the mechanical and bactericidal value of this increased secretion is speedily visible This is followed in many cases by rapid healing of chronic sinuses Caution is, however, very necessary This method of treatment is rarely suitable in the very young, old, or very weakly It is contra indicated in many complicating conditions, e g diseases of the heart and kidneys It is unsuitable also in amyloid disease It should be gradually and progressively employed in those cases deriving benefit, individual idiosyncrasy being carefully observed

The best state of the tide for complete immersion is usually about one hour before high water, the best time, the sunny forenoon about one hour before the midday meal, the combined absolute optimum

is not always, of course, obtainable. After a successful course of therapeutic sea-bathing, combined with intensive insolation in subjects trained to undergo this form of treatment, the improvement in the general condition, physique and local lesions is so marked as to be almost incredible.

X-ray Treatment

X-ray therapy is of value in the treatment of certain local tuberculous lesions and, synchronously with their amelioration, general improvement is often observed and maintained. Its value is due to the local reaction, and its success necessarily depends on the skill of the operator in obtaining just the local reaction desired. It is desirable to work on definite lines and with limited dosage. The technique advised by Iselin is the best I know. The value and applicability of X-rays vary in different regions of the body: the greatest care should be exercised in treating the extremities and the neighbourhood of the growing points of bones. Obviously, radiotherapy is contra-indicated in tuberculous disease of the genital organs on account of the risk of sterility. It is useful in certain cases of sinus-formation, particularly in old sinuses with thick fibrous walls. It is commended by many in the treatment of lupus vulgaris, but other and more effective methods may be employed for this distressing condition. It is especially valuable in tuberculous adenitis, particularly when there is much periglandular infiltration, and is a useful treatment preliminary either to extirpation or aspiration. It may often be usefully employed in tuberculous disease of the neck, elbow, or knee joint. In tuberculosis of the hands and feet, great care is desirable in its application, as X-ray burns or other unfortunate sequelæ more readily arise in the extremities, but with limited dosage and adequately filtered exposure it is often attended with considerable success. It is sometimes helpful in assisting the liquefaction of thick or caseous pus in abscesses.

MECHANICAL TREATMENT

Recumbency is generally essential for severe and acute lesions, but, in addition, apparatus for immobilization is often indispensable. Plaster of Paris and celluloid may be considered here.

Plaster of Paris.—It would be feasible to treat almost every case of extensive bone and joint tuberculosis by plaster of Paris splints alone. In certain cases deformity may be corrected, and in almost all cases prevented. Nevertheless, such an extreme use, though valuable, is not advocated. It is unfortunate that the value of plaster of Paris is so ill recognized in this country and the technique of its employment so ill understood. It affords a ready means always available for the surgeon to be his own efficient splint maker, but for plaster of Paris to be really satisfactory, skill in its application must be acquired and suitable plaster bandages used, which must be neatly applied, properly reinforced to combine strength with lightness, and *properly moulded*. The moulding is perhaps the most glaring defect in the plasters usually seen. To immobilize a joint satisfactorily the plaster should not only be effectively moulded, but also should

extend a sufficient distance above and below the joint Thus for a knee joint it is not sufficient to apply the apparatus half way up the thigh or half way down the calf the minimum efficient extent is from the ankle to the hip joint and in very acute disease both ankle and hip-joint should be incorporated

Plaster of Paris is especially valuable after the most acute stage of the disease is passed when muscular spasm is abating and when healing and consolidation are commencing and will be hastened by continued immobilization It may be used while the disease is very acute but other methods of fixation are then as a rule to be preferred

The plaster bandage—Specially prepared muslin stiffened by dextrin glue or starch though commonly used is quite unnecessary and indeed not so serviceable as ordinary book muslin of about 32 strands to the inch This should be torn in strips of suitable width and length and the edges

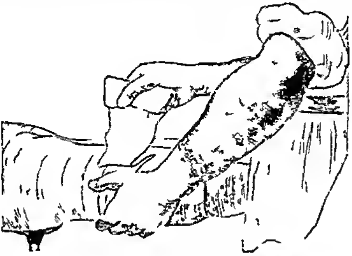

Fig 8—Application of plaster of Paris in tuberculous hip-joint

Note method of pleating bandage

frayed to avoid the annoyance of strips of cotton catching the fingers during application The bandage should be *loosely* rolled in a large shallow bowl containing fresh warmed dry superfine plaster of Paris in such a way that enough plaster is incorporated With a little practice excellent bandages can be quickly manufactured without the labour of rubbing in the plaster

For a splint the bandage should be soaked in cold water as the resulting set is firmer for a cast warm water is better as the set is more rapid Setting may be hastened or delayed by the addition of accelerators such as common salt or retarders such as dextrin but they are rarely required and their use is not advocated A closely fitting vest turned inside out should be applied to the trunk or limb to be plastered The loosely rolled plaster bandage is put gently sideways into a full bowl of water to ensure rapid and thorough contact of water and plaster To remove the bandage from the bowl each end is grasped by a hand and the bandage squeezed tightly as it is lifted out to get rid of surplus water without disturbing the plaster

Bandages should not be wound straight round a limb or trunk but

upwards or downwards, to avoid undue constriction A reverse should never be made in a plaster bandage, for the same reason A pleat in the bandage should be made whenever the direction of application is altered, and also to allow room for expansion of the subjacent trunk or limb before the set (Fig 8) All bony joints should be most carefully protected and the plaster moulded over them e g in a spinal jacket, the whole of the pelvic brim around the clavicles, scapulæ and each side of the spine over the transverse processes Ample windows should be cut out in a jacket over the ventral surface of the body, to allow room for respiration and digestion, in the region of affected joints, to permit observation The edges of the apparatus should be trimmed the subjacent vest turned over the plaster and stuck down by plaster cream (5 parts plaster 3 parts water) When dry the apparatus should be polished with plaster cream, this improves its appearance and lengthens its life When necessary, the apparatus may be reinforced by strips of plaster bandage which may be moulded into the form of a thin rod adhering to, and incorporated with, subjacent plaster and following accurately its contours Foreign substances, strips of tin, wood, etc, should not be used for reinforcing as they tend to work loose Where extensive windows have to be cut, e g over large sinuses, the plaster apparatus may be strengthened, if desired, by bridges of plaster bandage as in reinforcing work

Before a plaster jacket is applied to a suspended patient, he should have gradually been tilted to an erect position on a spinal board until he can assume and maintain the erect attitude without discomfort. Care should be taken to prevent the formation of sores under the plaster, by preparing the skin before application and by avoiding undue pressure on any surface with bone immediately subjacent A plaster-sore which is forming can usually be detected before the skin is broken, as it is heralded by an unpleasant smell These sores are usually painless, and patients may be unaware of them

A good plaster apparatus should be light strong, and well moulded

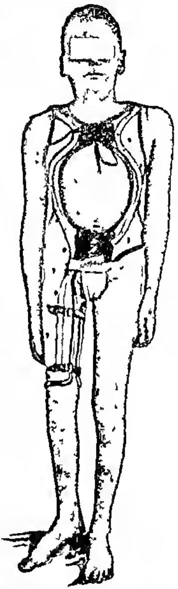

Fig 9 — *Celluloid splint strengthened with duralumin for combined spinal caries and tuberculous hip joint*

Note ventral window which should always be provided in spinal jackets

Celluloid.—Celluloid splints are now deservedly popular, and are especially indicated during convalescence in bone and joint tuberculosis They are light, elegant, clean, hygienic, and readily removable When well made they afford admirable support and protection Combined with blued or nickelled steel or duralumin, they may be used in an infinite variety of ways and for almost all conditions A cast of the region to be splinted is taken, from

it a positive is made on which non inflammable celluloid solution is painted on to successive layers of butter muslin, until the requisite thickness is obtained The splint is then removed from the cast, tried on the patient unnecessary parts are cut away, and the edges bound with leather Holes are punched in the splint for ventilation eyelets inserted for lacing and the splint, if necessary is reinforced with duralumin, or other appropriate metal (Fig 9)*

LOCAL ORTHOPÆDIC TREATMENT OF INDIVIDUAL LESIONS

It is impossible adequately to discuss here methods of correction or prevention of deformity Nevertheless skilled local orthopædic treat-

Fig 10 —Spinal board and jacket for spinal caries

ment, within the limits prescribed by the fact that the patient is tuberculous, is indispensable to good final results During the period when considerable local lesions are acute, rest is eminently desirable, and that is best effected by recumbency combined with immobilization Simultaneously, means must be taken to prevent or correct deformity The methods adopted to secure this end vary widely, but the principles are essentially similar

Spinal caries.—In acute disease, recumbency, combined with immobilization of the spine, and hyperextension if there is no or only slight, deformity, is usually effective This may be most easily obtained by the use of the Berck spinal board and jacket (Fig 10), which combines in a simple form the essentials for treatment in all forms of acute spinal caries

Some surgeons are content with immobilization in a double Thomas hip-splint or on a Phelps box The Bradford frame, popular in America, is preferable to either Immobilization on a plaster of-Paris bed (Lorenz) has advocates and is efficient In certain cases specially designed apparatus is desirable Thus, in acute cervical caries, fixation of the head is indispensable, for these cases a plaster bed or box splint, to immobilize the head and neck, is much to be preferred to the sandbags commonly employed, which are too easily displaced (Fig 11.)

With marked psoas spasm but not much deformity, the "wheelbarrow splint, with its removable back door, is efficient. It secures

* Full details of manufacture are to be found in the *Brit Med. Journ.*, June 7 1913, i, 1200

good hyperextension simultaneously fixes the legs and at the same time permits ready inspection of the back (Fig 12)

With moderate degrees of deformity without much spasm the

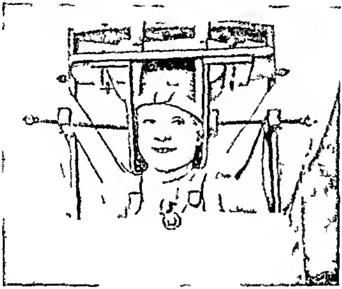

Fig 11 —Head fixation and extension in cervical caries

This form of fronto-occipital extension needs no chin strap, it increases the patient's comfort and avoids injury to the jaw

swinging back door splint is of value and assists in the correction of deformity (Fig 13)

Generally speaking however the Berck board with a jean jacket for fixing the trunk is the simplest and at the same time a very effective appliance

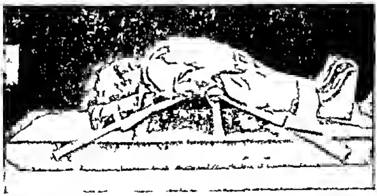

Fig 12 — Wheelbarrow type of back door splint for acute spinal caries with psoas abscess or psoas spasm

In spinal caries with extreme deformity attempt at correction may be cautiously made by the author's Marconi apparatus Essentially, its object is to straighten out as far as possible compensatory curves

above and below the lesion, and to expose the deformity to graduated and gradual tension with subjacent pressure Great care must be taken to avoid dissemination of the disease or pressure on the cord causing paresis but in suitably selected cases with careful nursing remarkable correction of severe deformity is possible

When there is inflammatory paraplegia, not due to mechanical pressure recumbency and immobilization associated with head and leg extension are usually effective

When an abscess is pressing on the cord laminectomy or costotransversectomy may have to be considered after a fair trial of recumbency Calve has suggested an ingenious method of aspirating such an abscess through the intervertebral canal but it presents considerable difficulties and is as yet of uncertain value

Of recent years much attention has been directed to bone-grafting

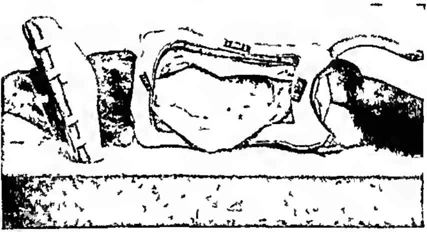

Fig 13 —" Back-door splint in spinal caries, with door removed

of the affected spine by the method of Albee, or one of its modifications In young children in acute cases this is associated with danger and is not here advocated In adults it is less dangerous, but in my opinion is not justified in acute cases when skilled conservative treatment is available The period of recumbency is alleged to be materially shortened by this procedure, but there are objections which I believe more than balance the advantages, except in a few specially selected cases Its general adoption should be condemned while the disease is active

Recumbency should, where possible, be enforced until spinal rigidity has disappeared and as much deformity as possible corrected In cases treated early little or no deformity should occur When recumbency is abandoned, immobilization as perfect as possible should be continued until the spinal lesion has well consolidated and all evidence of activity, both clinical and radiographic, has disappeared The minimum period after the onset of the disease, in favourable circumstances for immo-

bilization, should be about two years, and in cases treated inefficiently at the onset, or in which satisfactory progress has not been made, this may have to be extended

When recumbency is first abandoned, a well-moulded plaster-of-Paris jacket (Fig 14) is the best method of fixing the spine It is replaced later by a removable appliance, when in most cases the needs of the patient are best met by a well made celluloid jacket, and last of all by a Taylor's brace, modified, if necessary, for the needs of the individual

In cervical caries a poroplastic collar, or one of celluloid or leather, is sometimes employed, but is not so efficient as a jacket of similar material taking purchase from the pelvis and extending to chin and occiput, or, in the case of a young subject, with a jury mast incorporated

Correction of deformity in a plaster jacket, as recommended by Calot, is not advocated, and deformity in a tuberculous spine should never be forcibly corrected

The mechanical treatment of spinal caries affords numerous opportunities for the employment of various orthopædic measures specially applicable to individual cases, and often requiring modifications at different periods in the course of the disease

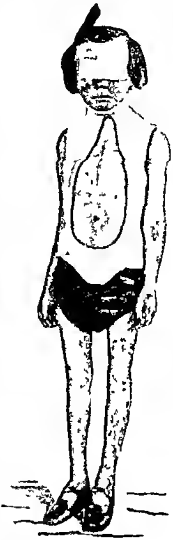

Fig 14 —Minerva plaster-of-Paris jacket in cervical caries

Hip-joint.—Tuberculous disease of the hip-joint, when acute, should be treated by recumbency combined with extension The following rules should govern the direction on which the leg is extended

If there is lordosis (1) the femur on the affected side should be further flexed until the spine is flat upon the bed (2) the two anterior superior iliac spines should be on the same horizontal plane, (3) the straight line joining these spines should be at right angles to the long axis of the trunk

Suitable extension applied to the femur on the affected side in the position it now occupies will be effective, provided the joint is not fixed by bony ankylosis In addition, the patient should be nursed on a fracture-bed and the trunk fixed to the healthy side, either by a jacket or by a Liston long splint The flexed leg must be supported on a suitable plane or on pillows

Various materials may be used for the extension Commonly, adhesive strapping is applied to the leg and attached to a stirrup below

the foot, from which the extension proceeds to a suitably fixed pulley Celluloid solution or Sinclair's paste makes an efficient adhesive to a strong calico bandage, instead of strapping Webbing carefully bandaged on the leg without adhesive is quite efficient if skilfully applied In place of the stirrup it is better to use a footpiece, which has the advantage of preventing foot-drop and heel sores, and of counteracting any tendency to inversion or eversion of the leg (Fig 15)

When heliotherapy is being simultaneously employed the condylar clamp extension, in use at Alton is advocated This has the advantages of extreme simplicity, of ensuring direct traction on the femur, and of avoiding injury to the knee joint, besides preventing foot-drop It

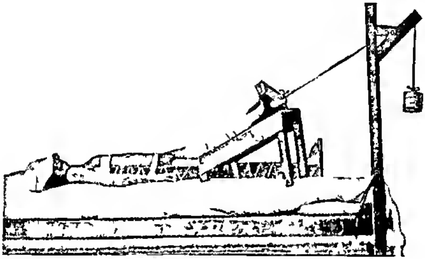

Fig 15—Extension applied in tuberculous hip joint with flexion adduction and inversion
Plaster strapping is not used in this form of extension, and the footpiece is designed to prevent foot-drop and avoid heel sores.

is easy to apply, comfortable and economical but its use should not be excessively prolonged (Fig 16)

Extension is as a rule advised not only until all deformity has been corrected but until all signs of active disease have disappeared The most valuable clinical evidence of cessation of active disease is afforded by absence of muscular spasm in the abdominal muscles on slight, sharp rotation of the femur, a sign which obviously should not be sought until the grosser signs of active disease have disappeared Ambulatory treatment may then be started with confidence, the patient's affected hip being fixed either by a short well moulded plaster spica, or by a celluloid hip splint, with crutches and patten on the sound leg When a patten is objected to a metal extending ambulatory hip-splint (Fig 17) may be substituted

A single Thomas hip splint is not effective in the treatment of tuberculous disease of the hip joint, and is not recommended

In cachectic or other cases in which early ambulatory treatment is

indicated, it may be permitted as soon as deformity is corrected, a plaster spica being then, as a rule, the best means of immobilization, as a plaster is the most promising appliance for preventing return of deformity. Great care must be taken in the moulding of the spica, and particularly in covering the buttock well on the affected side, as otherwise considerable deformity may occur. Crutches and patten are essential. Alternatively, a traction hip-splint may be useful. Ankylosis often follows, but the hip is fixed in the position selected. Where possible, however, a healed movable hip is preferable to one fixed by fibrous ankylosis. In the latter case extra-articular bony arthrodesis is indicated.

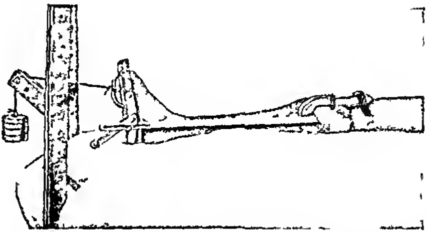

Fig. 16.—Condylar clamp extension for tuberculous hip joint and other conditions, especially indicated during heliotherapy.

Note footpiece provided with rollers to prevent plantar flexion of foot and reduce friction during extension.

Where sinus-formation has been prevented, operative interference in tuberculous disease of the hip joint is rarely, if ever, required, save in those cases in which, owing to inefficient initial treatment, bony ankylosis in an unfavourable position has occurred. Then sub- or trans-trochanteric or bifurcation osteotomy should be performed, and tenotomy of the adductors may also be necessary. After the operation the leg is fixed on an abduction frame, or in a long plaster spica extending from the toes to above the iliac crests until firm bony union has been established. In cases terminating in imperfect fibrous ankylosis, with persisting tendency to adduction deformity, arthrodesis is often of the greatest value.

It may be of interest to mention here certain types of cases of non-pulmonary tuberculosis, particularly of hip disease, in which, although after suitable treatment the local lesion becomes quiescent, the patient remains persistently cachectic. This persistent cachexia should be regarded seriously. It is commonly an indication of latent, sometimes generalized, tuberculosis which almost invariably manifests itself later—very much later perhaps—by recurrence in the old lesion or recrudes-

cence in some new focus. Such patients should be watched for a long time after discharge, until the cachexia disappears. They should be warned of the probability of a recurrence, and means taken, where possible, to ensure that they live under healthy hygienic conditions.

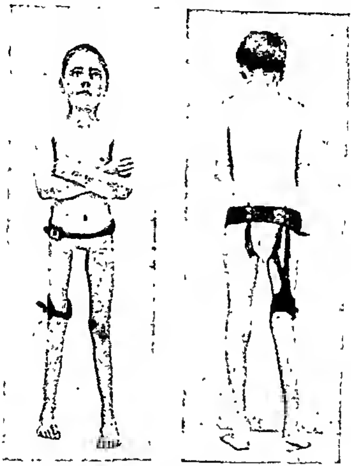

Fig. 17.—Metal splint for tuberculous hip-joint.

Knee-joint.—In children, in the early and acute stages, plaster fixation is advised, the plaster extending from the toes to the groin, and an *observation window* or *windows* should be cut in the region of the joint to ensure that no abscess develops unperceived.

Deformity, if extreme, consists not only in flexion at the joint, but also in subluxation of the tibia, with eversion. If recent, this may be corrected by appropriate extension (Fig. 16); if extreme, tenotomy of the biceps femoris is often necessary, combined with gentle and repeated correction under anæsthesia, and plaster fixation after each manipulation. Manipulation must be very gentle, and forcible correction should always be avoided.

Plaster fixations are continued until muscular spasm has disappeared and the X-rays show definite evidence of recalcification Then the child should have a celluloid knee splint with crutches and patten or a Thomas calliper knee splint which just raises the heel of the foot off the boot, and the heel of the boot on the sound leg must be appropriately raised

In adults, tuberculous disease of the knee joint is often exceedingly chronic In such cases early excision is generally better than prolonged conservative treatment

Other tuberculous bone and joint lesions hardly merit further con-

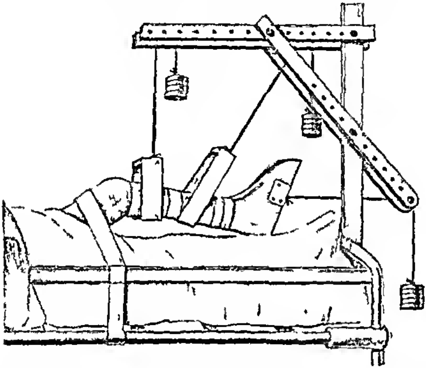

Fig 18 —Extension in tuberculous knee joint designed to correct subluxation of the tibia

sideration here the general principles already laid down are applicable in their treatment A rare but serious condition is tuberculous disease of the flat bones of the skull Here the diploe frequently becomes involved, and general dissemination follows with correspondingly bad prognosis

TUBERCULOUS ADENITIS

The broad principles of treatment which I have outlined apply equally in tuberculous glandular conditions There has been much recent controversy about the treatment of tuberculous glands of the neck and that may be to some extent explained by the varying facilities for treatment available to various practitioners In some cases a purely conservative approach is obviously sufficient, in others

radical treatment is equally obviously called for I here briefly outline my usual procedure First seek the probable source of infection e g infected tonsils or teeth and eradicate it Next apply the rules laid down for all tuberculous lesions—general and local rest under favourable hygienic conditions Local rest is frequently omitted in cervical glandular lesions but is just as efficient and even more simply applied than it is in tuberculous joints I use a simple metal splint which I call a carapace because it was evolved from a much more cumbrous plaster appliance

It consists of a light sheet iron band about 2 inches wide which fits neatly to the back below the scapulæ and extends from each mid axillary space This is padded with chamois and strapped by webbing to the front of the chest From this base a light duralumin bar shaped to the back and neck extends to the occiput From here a band of sheet iron grips the occiput and extends to the fronto-parietal suture comfortably above the ears and strapped across the forehead The whole splint is covered with chamois It is light comfortable and efficient All movements of the head are prevented and the affected glands kept at rest

In early glandular cases with good resistance as recorded by the blood sedimentation rate these simple measures will often suffice and the glands will be absorbed and disappear without further treatment

Where one or two glands contain pus these may be simply evacuated by the insertion of a silk seton This is more effective and less painful than repeated aspiration and affords a ready means of discharge of the pus Moreover the presence of the seton in the gland promotes the liquefaction of its contents and in most cases within a fortnight or three weeks only a harmless fibrous gland capsule remains which while protecting the surrounding tissues from further infiltration will in course of time shrivel up and disappear

Where there is much periadenitis an initial short course of X ray treatment on the cross fire plan is often of great value for the glands become more discrete and easier to deal with When patients arrive with pus containing glands adherent to reddened skin it is useful to insert a small sharp-pointed tenotome into the most dependent part and express the pus This may be repeated as and when required Sun treatment may be used advantageously in suitable cases bearing in mind that excessive light treatment may encourage pus formation in the glands This fact I utilize to advantage in certain cases Indolent glands may often be beneficially influenced and rapidly drained

Hard or caseous glands which do not respond to conservative treatment should be completely excised Preliminary conservative treatment is always helpful and the subsequent excision facilitated

Glands which have broken down and formed sinuses are usually secondarily infected The discharge will be increased and healing hastened by combined local and general ultra violet light treatment sometimes combined with therapeutic sea bathing Some septic tuberculous gland sinuses will not heal because of the presence of

infected calcified material acting like a sequestrum This should be removed by operation

Tuberculous adenitis is one of the most satisfactory tuberculous conditions to treat, provided the various methods of treatment which may be adopted are thoroughly understood and intelligently applied

ABDOMINAL TUBERCULOSIS

Tuberculous abdominal lesions glandular peritonitic or ulcerative, more commonly come for treatment than they used to, this is all to the good and may be attributed to earlier diagnosis Their more speedy diagnosis and successful treatment has, in my opinion, done much to prevent dangerous dissemination It is sometimes forgotten that they are frequent sequelæ of pulmonary tuberculosis, and their possible, and in many cases probable, incidence should not be overlooked in any case of lung infection

When primary, they are often of bovine origin In addition to the usual treatment on well recognized principles certain special measures should be advocated Full blood examination with differential count and blood sedimentation tests are of the greatest value Fæces should be examined for occult blood and tubercle bacilli and for signs of intestinal ulceration as divulged by the Triboulet test The value of this test is disputed, it certainly is not pathognomonic of tubercle infection, but when positive in a tuberculous subject its significance should be appreciated A fibre free diet should always be prescribed Pain, which is mostly colicky, is relieved by local heat and pressure applied by a firm many-tailed bandage

The most dangerous complications are obstruction (generally due to adhesions), intussusception and perforation These often need surgical treatment It is amazing to see how very advanced inflammation revealed on laparotomy will, in the course of a few weeks or months, completely subside after appropriate treatment Pain is often relieved by a combination of radiant heat and ultra violet light Caution should be exercised in employing the latter when pulmonary tuberculosis is also present and the pulmonary area should not be exposed The discovery of short-wave rays offers possibilities of further relief in selected cases

A discussion of the conservative treatment of surgical tuberculosis would be incomplete without reference to the collaboration of a skilled pathologist Full blood and differential white counts, hæmoglobin estimation and sedimentation rates are of value both in the conduct of treatment and as aids to diagnosis Estimation of the calcium and phosphorus content of the blood is often helpful Bacteriological, hæmatological and chemical examination of the stools is of further help, and it goes without saying that pus in abscesses and discharge from sinuses should be bacteriologically examined

PROGNOSIS IN SURGICAL TUBERCULOSIS TREATED BY CONSERVATIVE MEASURES

In estimating the value of conservative measures it is desirable to give accurate figures of the results of treatment Most records from foreign sources refer to private patients who may enter or leave an institution at will I am therefore, confining my records to those patients who were admitted to the Treloar Cripples' Hospital, Alton who, unless removed by parents or transferred for some special reason, have completed treatment, and I shall not refer to patients treated by me privately or in other institutions Appended is the record of patients admitted for non pulmonary tuberculosis from the opening of Treloars in September, 1908, to March, 1938, i e , a period of nearly thirty years

Lesion	Total admitted	Total discharged	Total completing treatment	Total disease arrested	Total removed or transferred	Total died	Percentage completing treatment with disease arrested	Average stay in days
Spine	1,771	1 702	1 542	1 476	160	66	86 7	581 8
Hip	1 903	1 818	1,722	1 669	96	58	91 7	626 4
Knee	749	726	693	679	83	14	98 5	845 8
Other	1 367	1 296	1 226	1,203	70	23	92 8	854 8
	5 790	*5 542*	*5 183*	*5 027*	*359*	*156*	—	—

Of the various surgical tuberculous lesions, undoubtedly the most dangerous is tuberculous disease of the spine and the younger the patient the higher, as a rule the mortality

I here extract from a contribution to the *Lancet** certain facts regarding mortality and prognosis in cases of spinal caries in children treated conservatively

Mortality is highest in the age period 1 to 5 , the commonest cause of death then is meningitis and general tuberculous dissemination. As age increases the danger of meningitis diminishes, but deaths from sepsis increase Other causes may be almost disregarded as they are incidents arising in any child s life though such incidents are naturally more serious in a child already infected with tuberculous disease This comparatively low mortality in children—many of whom arrive for treatment with advanced disease, often complicated by abscess or sinus formation and sometimes by paraplegia—may be ascribed to the rigid conservatism practised under exceptionally good climatic and hygienic conditions

* March 7 1936 1 567

Spine

Total number of cases admitted during the period	1666
Cases discharged to March 31 1935	1582
Deaths to March 31 1935	61 (3 8 per cent)
Average stay in hospital of fatal cases	410 days

Causes of Death

Miliary tuberculosis and meningitis	32 (2 02 per cent)	
Sepsis and amyloid disease	16 (1 01 per cent)	
Other causes	13 (0 82 per cent)	
Diphtheria	1	
Morbus cordis	3	
Nephritis	1	
Ketosis	1	
Tuberculous carditis	1	
Postoperative shock (laminectomy)	1	
Pneumonia	1	
Broncho pneumonia	1	3
Influenzal pneumonia	1	
Intestinal obstruction	1	
Hæmorrhagic measles	1	

Age Periods	Deaths	Average stay in days	Miliary tuberculosis and meningitis	Sepsis and amyloid	Other causes
1— 5	26	257	19	2	5
6—10	26	592	11	8	7
11—16	9	466	2	5	2

Relative Frequency of (a) *Miliary tuberculosis and Meningitis and* (b) *Sepsis and Amyloid Disease as Causes of Death at different Age periods in Spinal Caries*

Age	1 5	6 10	11–16
Miliary tuberculosis and meningitis	73 1 per cent	42 per cent	22 2 per cent
Sepsis and amyloid disease	7 7	30	55 6

An abscess is a serious complication when it forms in the region of the spinal canal and when by reason of the pachymeningitis it produces or by direct mechanical pressure it involves the spinal cord The mid and upper dorsal regions of the spine are the commonest situations Of 134 cases of paraplegia occurring at the Treloar Cripples Hospital 14 are still under treatment 5 died 6 were removed from hospital 24 were unimproved and 85 were discharged walking after conservative treatment

Paraplegia from true tuberculous pachymeningitis is a late manifestation, its onset is insidious, it tends to progress rather than resolve and the prognosis is bad. Of 26 such cases included in the total of 134, 12 recovered, 11 were unimproved, 2 were removed and 1 died.

Association with other Tuberculous Lesions

Occasionally, though rarely, patients fail to respond to any form of treatment and develop other lesions. For these, prospects of recovery are poor, though at times from some reason, possibly a suddenly acquired immunity, the progress of the disease is checked and recovery follows.

In children, multiple lesions associated with spinal caries lengthen the period of treatment required but do not usually jeopardize the cure. Associated pulmonary tuberculosis is a serious but not unconquerable complication, and I have known adults who, as a result of acquiring spinal caries after pulmonary tuberculosis, have recovered completely from both, largely owing to the enforced rest which the spinal lesion necessitated.

For details of design of institutions suitable for the treatment of non-pulmonary tuberculosis the reader is referred to the author's Oration to the Medical Society of London, under the title "Planning a Hospital" which appeared in the Society's Transactions 1928 liii, and *Lancet* 1938, ii, 95.

CHAPTER III

GENERAL ORTHOPÆDICS

By the late R C. ELMSLIE, O.B.E.

INTRODUCTION

THE chief object of orthopædic surgery is the restoration of function in a part that is disabled by maldevelopment, injury or disease Improvement in shape or appearance may be desirable for æsthetic reasons, but in every case the effect of operative or other methods of treatment upon physical function should be studied Moreover, it is necessary to remember the future as well as the immediate result For example, operative or manipulative procedures upon a joint may result in improved function for a few years, but experience may show that they are unjustifiable because they lead later to the degenerative changes of osteo arthritis Arthrodesis and tendon fixation carried out upon young children improve function but may interfere with growth, or growth may result in an alteration of strains which tends to produce a fresh deformity

In an actual deformity there may be a contracture of skin, muscle, tendon or ligament holding one or more joints in a fixed position or restricting their full range of movement, a joint may be dislocated or a bone malformed or crooked, or there may be an actual loss of part of a limb as the result of congenital maldevelopment or of injury or disease But in other cases the condition which requires treatment is a loss of function rather than of shape Such are many paralytic conditions (anterior poliomyelitis, spastic paralysis and peripheral nerve injury) and injuries of muscles tendons and ligaments

In the first of these groups the correction of shape must be subordinated to the improvement or maintenance of function The simplest and most direct surgical method may not be the best For example, in congenital club foot, the shape of the foot can be corrected by a gross surgical operation, the removal of a part of the tarsal bones, but this interferes with the action of all the tarsal joints and leaves a foot which looks a good shape but is really only about as useful for walking purposes as a stump Scarring of the skin often interferes with mobility or even causes deformity If this possibility is realized in advance much may be done to prevent it The part may be splinted during healing to prevent contracture, the skin around may be kept supple by massage, and in suitable cases a granulating area may be excised, the skin undercut and mobilized, and a secondary

suture carried out In grafting skin the effect upon function should be remembered Areas covered by Thiersch or Wolff grafts usually show adherent scars If the graft has to cover exposed tendons these grafts will not give satisfactory results and a pedicle graft will be required The same may be true when muscle is exposed or when the scar is left adherent to the capsule of a joint

Deformities in which muscles or tendons are shortened are not necessarily to be treated by division or lengthening of the tendon This procedure inevitably weakens the muscle and the resulting loss of power may be important Efforts should be made to correct the shortening by milder methods of stretching by hand or by exercises as well as considering the possibility of manipulation under an anæsthetic or some form of extension In some cases it may be wiser to leave the deformity This is often the case when the tendo Achillis is a little short in a paralysed and weakened leg Lengthening the tendon further weakens the calf muscle and in addition it allows the foot to dorsiflex beyond the right angle position When weight is placed on the foot the knee is forced into hyperextension in which position it is stable even if the quadriceps is weak or absent

Contracted ligaments may require division but it should be remembered that some ligaments are essential to the stability of the joint They should if possible be stretched rather than cut

If a bone is crooked as the result of injury or disease it may perhaps be straightened by osteotomy But it is not essential to carry out this operation at the site which is anatomically correct Whenever possible the osteotomy should be performed at a level at which the bone is normal and not at the site of old disease or injury Stiff joints can sometimes be mobilized by the operation of arthroplasty But before this is undertaken the surgeon should decide whether the function required is better with a sound fixed joint than it would be with the rather imperfect and perhaps unstable joint which results from the operation

When there is loss of function rather than deformity all possible non operative methods should be considered first This is particularly the case in paralytic deformities and the use of splints appliances massage manipulations exercises and re education should be given a prolonged trial before such operations as arthrodesis and tendon transplantation or fixation are advised

In fact in orthopædic treatment operation is only one part of the work It should be used only after careful consideration and as part of a planned campaign in which the pre-operative and postoperative treatment is just as important as the operation itself

OPERATIONS FOR CONGENITAL DISLOCATION OF THE HIP

The standard operation for congenital dislocation of the hip is manual reduction with fixation in plaster This operation is generally accepted as a reasonable method in cases of unilateral deformity up to the age

of 8 years and in bilateral cases up to the age of 7 Attempts at reduction at a later age may be successful, but they are usually considered inadvisable, because they may result in great stiffness of the joint or even in ankylosis The earlier the operation is carried out the better because reduction is far easier The acetabulum is more likely to be well developed in proportion to the head of the femur so that retention of the latter in the joint is more probable and recovery of movement after the period of fixation is more rapid and more complete

The manipulation may give rise to considerable shock Full and rather deep anæsthesia is therefore desirable The child lying on the back, an assistant fixes the pelvis and thigh on one side while the operator flexes the affected hip to a right angle and holding the limb by the knee, gradually abducts it at the hip joint The operator s other hand is placed behind the great trochanter and used as a lever to lift this forward By steadily increasing pressure upon the knee the limb is abducted until it lies flat on the table the adductor muscles being stretched and, to some extent ruptured The forward pressure upon the great trochanter pushes the head of the femur directly into the region of the acetabulum In simple cases during the manipulation the head of the femur is felt to slip into its socket with a definite click, if this does not occur further manipulations are tried with the limb in various positions of rotation, or with the hip flexed to a greater degree, so that the femoral head is directed more downwards When the head of the femur has slipped forwards and can be felt to lie under the femoral artery, the operation is complete and the limb ready for fixation in plaster of Paris In most cases when the head of the femur is in the acetabulum the hamstring muscles become tight so that the knee cannot be extended The best position for fixation is with the thigh abducted at right angles to the trunk and rotated inwards, so that the leg points backwards A thin layer of cotton wool or other padding is laid over the limb from the middle of the calf upwards, and over the lower part of the trunk and this area is then encased in plaster of Paris bandages In a bilateral case, if possible both hips should be reduced at one sitting so that they may be put up in a symmetrical position In unilateral cases it is better that the first plaster should include the thigh of the sound side, keeping it abducted at the hip

After reduction an X ray photograph should be taken through the plaster, to make sure that the femoral head is in the acetabulum This should show the great trochanter pointing downwards, the full angle of the femoral neck should be visible and the epiphysis should lie opposite the cartilaginous gap at the centre of the acetabulum

In many cases of congenital dislocation there is much anteversion of the femoral neck When this is present it is important to keep up strong internal rotation of the hip joint In many cases, if the limb is allowed to rotate out, the head of the femur at once begins to slip up over the margin of the acetabulum

The details of after treatment vary with different surgeons, and

must be to some extent varied in each individual case The position of the hip should be controlled by X-rays taken at intervals The minimum time for retention in plaster may be put at six months but this is only possible in unilateral cases in which the hip is reduced easily and remains securely in the acetabulum at the time of reduction The period is more often nine to twelve months in unilateral, and twelve to eighteen months in bilateral cases The first plaster should be retained for at least two months, in subsequent plasters the hip or hips are gradually brought into a more and more adducted position and, at the same time, into slight flexion In bilateral cases it is important to keep the position of the two hips symmetrical Inversion should be maintained and for this reason the plaster should be carried below the knee Some surgeons prefer to keep the original plaster on for a long period others change it every six or eight weeks Changes of plaster are advisable in older children (over 4 years) as there is a much greater tendency in them for the hips to become very stiff The child should not be kept recumbent during this long treatment, but may be propped up and carried about When the position of fixation allows it, the child may walk

When the plaster is removed the child may be left at first to recover mobility by its own efforts If the hips remain persistently stiff in a position of abduction the patient should be kept in bed, and extensions fixed to the limbs until they come down into a position that will allow walking Persistent stiffness is probably due to arthritis, and recovers better with extension than with manipulations and massage At a later stage massage and exercises will help to teach a proper method of walking

Various accidents have been recorded in carrying out this operation these include fracture of the neck of the femur, injury of the sciatic nerve, and rupture of the femoral vessels Most of these occurred in the early days of the operation, at the present time a fracture of the neck of the femur may take place in rare cases but is very exceptional

When attempts at reduction of the hips fail, the child may be left for two or three weeks and a second manipulation then carried out It is better not to fix the hip in plaster of Paris during this interval as the fixation may cause atrophy of the bone and lead to a fracture of the upper end of the femur when the second attempt is carried out

Failure to reduce may be due to the fact that the head of the femur is at a very high level, so that it is impossible to bring it down by the ordinary manipulations In such cases success has been obtained by using preliminary skeletal traction A pin is inserted through the condyles of the femur or head of the tibia and extension obtained by tying the cord attached to the stirrup to the end of the bed, which is then tilted up to an angle of 45°, or even more By this means the head of the femur may be pulled down 1½ or 2 inches in the course of a few weeks, and manipulative reduction can then be carried out

In other cases, failure to reduce is due to the fact that there is too tight a constriction between the false capsule in which the head of

the femur lies and the acetabular part of the capsule In such cases, reduction can only be obtained by an open operation in which the capsule is exposed and the narrow isthmus incised It is still doubtful whether this open reduction is justifiable or whether failure to reduce the hip on three occasions, and after the use of preliminary traction, should not be accepted as a contra indication to any further operative interference

Shelf operation.—In certain cases after an apparently successful reduction of the dislocated hip, the head slips up again to too high a level when the plaster is removed and weight is borne upon the limb Such cases are suitable for Fairbank's shelf operation This must, however, be performed at a stage at which the head of the femur can be replaced in the acetabulum without difficulty It is so reduced, and fixed in an abducted position in a plaster case for three to four weeks before operation An X ray should be taken to confirm the reduction

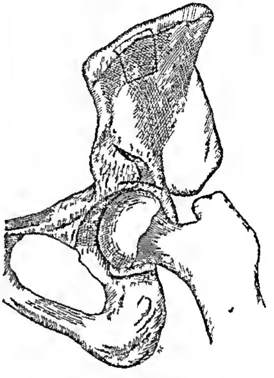

Fig 19 —Shelf operation for congenital dislocation of hip, showing incision on to bone

An incision is made along the anterior third of the crest of the ilium, extending downwards in a vertical line from the anterior superior spine The tensor fasciæ femoris and gluteus medius and minimus are separated from the ilium subperiosteally and turned outwards until the anterior inferior spine, the straight and reflected heads of the rectus femoris and the upper part of the capsule of the hip joint have been exposed The upper margin of the acetabulum is then defined above it lie the reflected head of the rectus, and the redundant part of the capsule which is attached to the ilium If this early part of the operation has been carried out with the limb lying straight down, it must be abducted and the head of the femur placed securely in the acetabulum at this stage

A curved incision on to the bone is made, parallel with and about half an inch above the upper lip of the acetabulum With a fine osteotome inserted along this line, an osteo-periosteal flap is cut and levered downwards until it lies in close proximity with the head of the femur, as the latter lies in the centre of the enlarged acetabulum This flap includes the margin and adjacent part of the roof of the acetabulum

A curved gap is thus left in the ilium A graft of bone sufficient to fill this gap and to project half an inch beyond it is cut from the upper part of the dorsum ilii, inserted into the gap, and wedged well home. (Figs 19, 20) As a rule it will stop in place securely, but if it does not it may be held in position by ivory pegs driven in obliquely above it. The muscles are then sutured, the wound closed and the hip fixed in the abducted position, as after manipulative reduction. The after-treatment is similar to that already described, but it is unnecessary to maintain right-angled abduction for more than three months.

Treatment of old unreduced congenital dislocations of the hip.—In cases of congenital dislocation of the hip which have not been reduced, or in which reduction fails, pain may later develop either in the hip or in the back, and osteo-arthritic changes may occur in the false joint. There may also be great instability because the head of the femur becomes displaced further and further upwards, failing to form any adequate false acetabulum In these cases the disability may become very great and some operative procedure is then required to improve stability and to lessen pain The best of these procedures would appear to be Lorenz's bifurcation osteotomy (Fig 21.) This operation is also suitable for some cases of pathological dislocation of the hip with much instability.

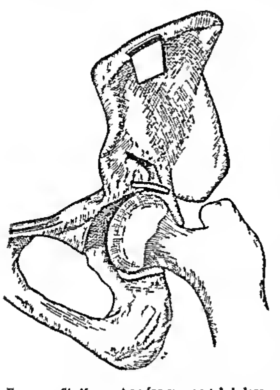

Fig 20.—Shelf operation for congenital dislocation of hip, showing graft in position

An incision is made along the outer side of the femur below the great trochanter The femoral shaft is exposed and brought into view by passing large bone levers in front and behind it. The bone is then divided with an osteotome in an oblique line directed upwards and inwards, starting on the outer side at a level below that of the acetabulum and terminating on the inner side at about the acetabular level When the bone has been cut completely through, the shaft is levered inwards until it lies obliquely against the cut surface of the upper fragment, the point on the inner side being pushed into the region of the acetabulum The adductor muscles are divided *subcutaneously*, and the limb fixed in a plaster case in whatever degree of abduction is necessary.

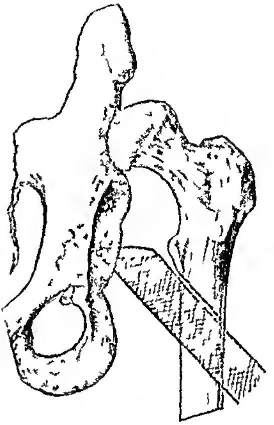

Fig 21 —Lorenz s bifurcation osteotomy

The plaster should be retained for a period of ten weeks in an adult The result of this operation is to keep the limb abducted and to form a buttress on the inner side at the site of the osteotomy This buttress lies against the pelvis in the region of the acetabulum and stabilizes the joint The subsequent mobility of the joint is diminished to some extent but there is generally sufficient movement to allow comfortable walking and sitting

This operation increases the shortening considerably It should be reserved for cases in which there is persistent pain It must be emphasized that many patients with unreduced dislocation of the hip or hips remain fairly comfortable throughout their lives without interference

OPERATIONS FOR STABILIZING PARALYSED FEET

In cases of infantile paralysis when certain muscles remain permanently paralysed procedures may be adopted to render the foot more stable and to dispense with external support which might otherwise be required The procedures include tendon transplantations and fixations and certain other operations upon bones and joints In planning these operations it is essential that there should be no hurry that a period of at least two years should have passed since the onset of the paralysis, and that adequate treatment by splinting, surgical appliances electrical stimulation and re education should first be carried out in order to secure as complete a restoration of muscle function as possible A premature operation upon a bone or joint leaves a result which it is practically impossible to undo It is undesirable also to perform these operations at too early an age The removal of portions of the tarsal bones in young children is apt to interfere with the growth of the foot It may be laid down as a rule that arthrodesis and similar operations should be postponed until after the age of twelve years

Arthrodesis—Arthrodesis is particularly indicated in cases in which there is a persistent valgus or varus deformity with much loss of muscle—for example in complete paralysis of the peronei and extensors of the foot and in talipes calcaneo-valgus The principle of the operation is the removal of sufficient of the articular cartilage of the joint to bring the bony surfaces into contact so that bony ankylosis may result At the same time a small wedge of bone may be removed in such a way as to correct any deformity present

Mid tarsal arthrodesis—An incision is made along the inner side of the dorsum of the foot over the head of the astragalus and the scaphoid just above its tubercle The astragalo-scaphoid joint is defined and the tendon of the tibialis posticus retracted downwards The tendons and vessels on the dorsum of the foot are all lifted so that the whole dorsum is cleared and a narrow elevator is pushed around the outer border of the foot With an arthrodesis gouge the cartilage covering the head of the astragalus and the corresponding facet on the scaphoid are removed If the astragalo-scaphoid joint only is to be arthrodesed—and this will suffice in many cases of valgus deformity—the operation is stopped at this point but if the entire mid tarsal joint is to be arthrodesed the articular surfaces of the cuboid and os calcis are similarly removed care being taken that the bones finally fit together in such a way as to produce a foot of normal shape The wound is then sutured and the foot fixed in plaster of Paris in the corrected position It is essential that in this position the heel and the heads of the first and fifth metatarsal bones shall be in the same plane so that they will meet the ground at the same time

Posterior subastragaloid arthrodesis—A vertical incision is made posteriorly along the inner side of the lower part of the tendo Achillis The tendon is lifted towards the outer side and the flexor longus hallucis cleared and drawn inwards In doing this the posterior tubercle of the astragalus comes into view and the subastragaloid joint lies immediately below this A vertical incision is made on to the joint and the ligaments are cleared away on each side until the whole of the margin of the joint is exposed a narrow elevator being pushed down on either side of the os calcis The articular surfaces of the astragalus and os calcis can then be removed with a fine bladed osteotome If the operation is being done for a calcaneus deformity the osteotome is so directed as to remove a small wedge with the base posteriorly If there is also a valgus deformity the inner side of this wedge is made a little thicker than the outer side

Triple arthrodesis of the tarsus (Naughton Dunn's operation)—A curved incision is made extending for about two inches vertically along the posterior border of the fibula turning forwards opposite the external malleolus and extending along the outer side of the foot as far as the base of the fifth metatarsal The peroneal tendons are exposed and retracted downwards and backwards The middle fasciculus of the external lateral ligament is divided and

the subastragaloid joint opened All the tissues are then lifted from the outer side and dorsum of the foot including the extensor brevis digitorum In this way the calcaneo cuboid and astragalo scaphoid joints are exposed and opened A narrow elevator is then pushed round the inner margin of the foot

After division of the interosseous ligament between the astragalus and the os calcis the whole foot is dislocated inwards below and in front of the astragalus so that the underneath of this bone the top of the os calcis and the posterior articular surface of the scaphoid are brought into view *(Fig 22)* The scaphoid is then removed entire care being

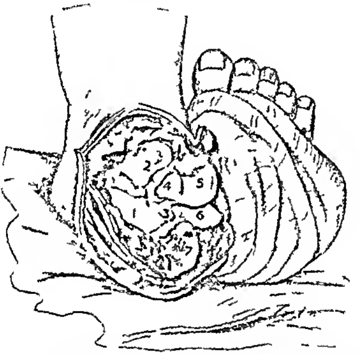

Fig 22 —Dunn s triple arthrodesis The joints are laid open by dislocating the foot inwards beneath the astragalus

1 The posterior facet on the os calcis 2 the posterior facet on the astragalus 3 the sustentaculum tali 4 the corresponding facet on the astragalus 5 the head of the astragalus 6 the scaphoid 7 the cuboid

taken in working round the inner side to divide the tibialis posticus tendon and calcaneo scaphoid ligaments There is a risk of fracturing the tubercle of the scaphoid and leaving it behind With an arthrodesis gouge the cartilage is then removed from the head of the astragalus the posterior articular surfaces of the three cuneiform bones and the articular surfaces of the calcaneo-cuboid and posterior subastragaloid joint The interosseous ligament between the astragalus and *the os calcis is dissected away and bone removed if necessary* until the remainder of the tarsal bones can be fitted together accurately with the foot a correct shape

The soft parts are then united with a few catgut sutures the skin sutured and the foot fixed in plaster in the corrected position It is

wise in this operation and in similar operations on the tarsus, to remove the tourniquet or Esmarch's bandage before the wound is sutured to tie any obvious bleeding points, and to wash out the cavity with hot saline solution

Lambrinodi's arthrodesis.—This operation is designed primarily for cases of paralytic foot-drop, either with or without power in the calf but without any power in the dorsiflexors The foot is fixed with the astragalus in a position of full plantar flexion so that when it is lifted from the ground the forefoot does not drop further

The first steps of the operation are the same as those for Dunn's triple arthrodesis, up to the point at which the foot is dislocated inwards below the astragalus The lower surface of this bone is then removed with a hand-saw by a transverse cut The upper surface of the os calcis is similarly cut away with a broad osteotome and the surfaces of the calcaneo-cuboid joint removed The anterior end of

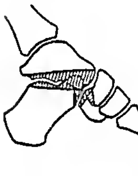

Fig 23.—Lambrinudi's arthrodesis The bone to be removed is shaded

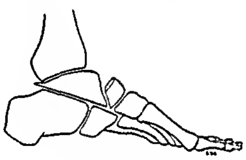

Fig 24.—Lambrinudi's arthrodesis. The denuded surfaces fitted in position

the cut astragalus forms a beak, a slot is now cut in the lower part of the articular surface of the scaphoid of sufficient size to allow the beak to fit snugly into it (Figs 23 24) when all the other cut surfaces are brought up into proper contact This slot should be cut right across the scaphoid as far as the inner border The bones are then held accurately in place the wound sutured and the foot fixed in plaster of Paris

The exact line of section of the astragalus depends upon the height of the heel that is to be worn Before operation a lateral X ray should be taken of the foot in full plantar flexion A tracing of this is made and the lines of saw-cut planned by cutting this, allowing for a heel of 1 or 1½ inches or whatever height is required

Whitman's astragalectomy.—This operation is intended as a substitute for a tarsal arthrodesis Originally designed for the treatment of talipes calcaneus it is also suitable for some cases of flail foot with a varus deformity The principle upon which it is based is that of abolishing the subastragaloid joint and substituting a single joint

between the tibia and fibula and os calcis for the ankle joint, sub-astragaloid and midtarsal joints, so that the foot moves with a simple hinge action and does not retain any lateral mobility

The incision is the same as for Dunn's operation The peroneal tendons are retracted in the same way, or may be divided and sutured subsequently The extensor brevis is lifted from its attachment and the dorsum of the foot cleared as far forwards as the astragalo scaphoid joint All three fasciculi of the external lateral ligament are now divided and the foot is dislocated inwards at the ankle joint By cutting through the interosseous ligament the capsule between the head of the astragalus and scaphoid, the middle portion of the internal lateral ligament and the posterior ligament of the ankle joint the astragalus can be removed entire This can usually be accomplished quite easily by cutting with a pair of curved scissors A pocket is then made on the inner side of the top of the os calcis in the region of the *sustentaculum tali into which the internal malleolus will fit* In some cases it is advisable to remove the sustentaculum with an osteotome A piece of bone is then cut off the outer side of the foot in the region of the calcaneo-cuboid joint, sufficient to narrow this part of the os calcis until it will fit well up between the malleoli In fitting it up in this way the whole foot is displaced backwards If it does not do so the foot will tilt over into a varus position When a proper fit has been obtained, the tourniquet is removed, bleeding stopped and the wound sutured, the foot then being fixed in plaster of Paris

After Whitman's operation, and after arthrodizing operations on the tarsus, the plaster should be retained for three months, during the last month the patient may be encouraged to walk on the plaster

OPERATION FOR PARALYTIC TALIPES CALCANEUS

A combined operation of arthrodesis, tendon transplantation and tendon fixation is used for the treatment of talipes calcaneus At the first operation Steindler's stripping of the under surface of the os calcis is carried out to flatten the arch and an arthrodesis of the astragalo-scaphoid joint is performed at the same time The foot is then fixed in plaster of Paris in strong dorsiflexion for a period of six weeks

At a second operation a vertical incision four or five inches long is made along the inner border of the tendo Achillis The tendons of the flexor longus hallucis, flexor longus digitorum, peroneus longus and peroneus brevis are isolated and divided as low down as possible Posterior subastragaloid arthrodesis is then carried out A strip of the tendo Achillis is fixed to the back of the tibia, holding the foot in about twenty degrees of plantar flexion, and the four tendons mentioned are transplanted into the tendo Achillis just above its insertion (*see* p 172) The foot is fixed in plaster of Paris in twenty degrees of plantar flexion and the plaster is kept on for a total period of three months

OPERATIONS FOR CONGENITAL TALIPES EQUINO-VARUS

The treatment of congenital talipes equino varus should be commenced as early as possible and unless the child is exceptionally delicate manipulative measures may be carried out within the first three months Wherever possible the correction of the deformity should be carried out entirely by manipulative methods without any cutting operation this applies to children of all ages

Manual correction —The child is anæsthetized and the surgeon attempts to unfold the foot with his hands taking each element of the deformity in turn He will first stretch to correct as far as possible the cavus deformity then the anterior part of the foot is grasped with one hand the heel with the other and the front of the foot is steadily abducted and rotated out Finally in this position of abduction and external rotation the foot is steadily dorsiflexed until it passes beyond the right angled position These several manipulations are not necessarily carried out at one sitting but they must be done in this order i e first the cavus deformity is corrected then the varus deformity and finally the foot is dorsiflexed over the right angle As soon as a correction has been obtained which is felt to be as much as is desirable for the moment the foot leg and knee should be fixed in plaster of Paris in a position of correction which is not quite the maximum obtained during the manipulation i e a position which can be held easily without undue force In fixation of the foot in plaster of Paris it is important to remember again the three elements of the deformity and that the foot must be flattened everted and dorsiflexed In order that eversion may be secured it is necessary to get some fixed point from which the foot can be twisted. This is only possible if the knee is flexed and included in the plaster A plaster case which reaches only as far as the calf can rotate upon the leg and allow the foot to invert moreover in small children such a short plaster is very apt to slip off A good method of applying the plaster bandage is to start upon the outer side of the leg and after a few turns round the heel and foot to bring the bandage from within outwards across under the anterior part of the sole From the outer side of the sole it is carried right over the top of the flexed knee this turn assists in holding the foot strongly everted and abducted With further turns the rest of the foot leg and lower third of the thigh are included After the plaster has been completed the toes should be inspected to see that the circulation in them is good

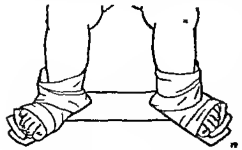

Fig 25 —Denis Browne s splints for congenital talipes equino-varus

Denis Browne s splints form a most efficient substitute for

plaster of Paris and, by holding both feet in a position of eversion and encouraging movements of the knees and hips in this position, are very successful in correcting the tendency to subsequent intoeing (Fig 25) It is essential to put both feet on splints even if only one is deformed The foot or feet are first corrected manually, if possible by one manipulation Each foot is then bandaged on to its splint

1 A felt or sponge rubber pad is placed under the outer border of the foot

2 The front part of the foot is securely bandaged down to the splint

3 The ankle is bandaged

4 A bandage is passed over the front of the ankle and behind the heel, thus holding the heel well into the splint

5 The leg piece, which so far has been ignored is brought up to the side of the leg and bandaged into place

6 When both feet have been separately bandaged, the cross piece between the splints is applied and the required degree of eversion adjusted

In children up to the age of one year no treatment other than manipulation and fixation in plaster or splints is advisable, except that it may be necessary to divide the plantar fascia subcutaneously At the end of a year, if there is real difficulty in dorsiflexing the foot beyond the right-angled position, a tenotomy of the tendo Achillis may be required In such a young child the lengthening operation described at p 160 may not be possible, and it may be necessary to divide the tendon completely

In older children up to the age of 5 or 6, correction of the foot should generally be carried out by one or more manipulations under an anæsthetic, without any additional cutting operation In rather older subjects, correction with the hand may not be possible and a *Thomas's wrench* (Fig 26) is then a useful accessory The best method of using it is as follows The foot is lightly padded with cotton wool and a firm bandage applied, the wrench is then fixed in the required position and screwed up as tight as possible so that it will not slip The limb is brought into such a position as will permit the handle of the wrench to be rested against the surgeon's hip The stretching movement can now be carried out by pressure upon the handle exerted through the hip, leaving the surgeon's hands free to support the limb and to feel what he is doing with the wrench In correcting a pes cavus the wrench is fixed on the foot with the distal bar over the dorsum and the proximal bar under the instep In correcting a pes planus the position of these bars is reversed To abduct the foot at the heel, the bars are fixed antero posteriorly below the malleoli, the body of the wrench lying behind the heel These are the three most useful positions for the wrench A steadily increasing pressure should be used, jerking and excessive force should be avoided After a forcible manipulation with the wrench, the foot should invariably be enclosed in a thick layer of cotton wool and firmly bandaged, whether plaster of Paris is to be applied immediately or not

For particularly resistant cases of talipes equino-varus in older subjects in whom manipulative methods have proved insufficient, many open operations have been devised That procedure should be

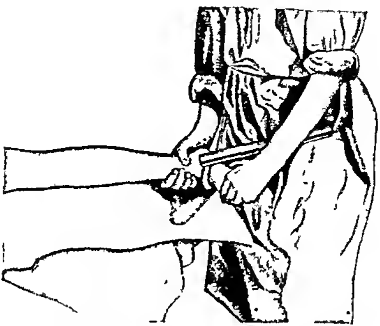

Fig 26 —Method of using Thomas s wrench by working with handle pressed against surgeon's hip

selected which will correct the foot with the least removal of bone and without *interference with the tarsal and ankle joints*

Capsulotomy of the astragalo-scaphoid joint.—In resistant cases of congenital talipes equino-varus the obstructions to correction are —

1 Shortening of the plantar fascia and muscles of the sole of the foot

2 Contraction of the anterior part of the internal lateral ligament tibialis posticus and the ligaments uniting the sustentaculum tali and the internal malleolus to the scaphoid

3 The os calcis is rotated so that its anterior extremity faces downwards and inwards its posterior extremity backwards, upwards and outwards It is held in this position partly by its ligamentous attachments in the region of the sustentaculum tali and partly by an adaptive alteration in the shape of the facets, which obstruct its return to its normal line beneath the astragalus

4 There may be an adaptive change in the shape of the neck of the astragalus, which points too much downwards and inwards

5 The equinus deformity is kept up by shortening of the tendo Achillis and of the posterior ligaments, but even when these have been freely divided it may be found that the astragalus will not return to its

normal position between the malleoli because the anterior portion of its upper articular surface is too wide

As a first step in open correction it is often advisable to do Steindler's operation of stripping the os calcis (*see* p 163) The next step, which may be carried out at the same operation, is division of the astragalo-scaphoid capsule A curved incision is made on the inner side of the ankle along the line of the tibialis posticus tendon This tendon is exposed right down to its attachment to the scaphoid bone It is generally advisable to remove it from this attachment The under surfaces of the sustentaculum tali and the scaphoid are then completely cleared, working close to the bone and dividing the other attachments of the tibialis posticus The remainder of the internal lateral ligament and the calcaneo scaphoid ligaments are then divided, cutting deeper and deeper until the knife meets the neck of the astragalus, which often lies at a very considerable depth

The object of this part of the operation is to separate the scaphoid internal malleolus and sustentaculum tali and to open the joint in front of and below the head of the astragalus When this is thoroughly opened it will be found that the anterior part of the foot can be abducted and a large proportion of the deformity immediately corrected

If complete correction is not obtained in this way it is probably because the os calcis cannot be brought into its proper position beneath the astragalus One method of combating this is to make an incision on the outer side of the foot in the region of the tarsal sinus and to divide the interosseous ligament, but even then correction may be insufficient because the surfaces of the astragalus and os calcis have become adapted to the deformed position and the bones will not remain in place

A simpler method is to make a small incision on the outer side immediately behind the calcaneo-cuboid joint, and to divide the os calcis transversely at this point The foot can then be abducted the scaphoid cuboid and small anterior piece of the os calcis all moving outwards After this operation the foot is fixed in plaster of Paris in a moderate degree of correction, and it is generally advisable to remove this first plaster case and to replace it with another in more complete correction at the end of two to three weeks

The other operations which have been advocated for the correction of congenital talipes such as astragalectomy and cuneiform tarsectomy, leave a very disabled foot and are inadvisable except in particularly difficult cases If an astragalectomy is performed, this should be done by Whitman's method If a wedge of bone is to be removed from the outer side of the foot because operations on the soft parts fail to secure complete correction of the varus deformity, the wedge should, if possible be removed without encroaching on the mid tarsal joints

Correction of resistant equinus deformity.—When the varus deformity is satisfactorily corrected but the foot will not dorsiflex

beyond a right angle it is seldom of any use to divide the tendo Achillis a second time In the circumstances an incision should be made posteriorly along the inner border of the tendo Achillis and the posterior ligament of the ankle-joint divided If the equinus still cannot be corrected the external malleolus should be divided with an osteotome at the level of the ankle joint so that it can spring outward and leave room for the widened part of the upper facet on the astragalus between the two malleoli

OPERATIONS FOR HALLUX VALGUS AND RIGIDUS

Three different operations are used for the treatment of hallux valgus In cases in which the deformity is not very severe but the symptoms are due to pressure upon the prominent head of the first metatarsal and to the formation of a bursa upon it excision of the projecting portion of bone (excision of exostosis) is usually sufficient to relieve the patient but it should be explained that this operation will not correct the deformity of the toe and therefore does not give a perfect æsthetic result It is inadequate in cases in which the big toe is sufficiently deformed to interfere with the movement of the second toe and also in cases in which joint movement is painful In all of these a complete excision of the head of the first metatarsal or else an excision of the base of the first phalanx combined with trimming of the head of the first metatarsal should be performed These two latter operations are also suitable for the treatment of hallux rigidus

Excision of exostosis —An incision is made starting on the dorsal surface of the distal end of the first phalanx and extending directly backwards over the head and neck of the first metatarsal The skin and subcutaneous tissue are reflected inwards and outwards and the deeper part of the bursa removed it is not necessary to remove the whole of the wall of the bursa If the latter is adherent to the skin and is dissected right away from it the indurated skin thus left may subsequently slough and give rise to difficulty in healing The incision is deepened along the same line until the joint has been opened and the capsule and synovial membrane are separated from the inner side of the head of the metatarsal and base of the phalanx the internal lateral ligament being completely divided It is generally advisable to dissect back the capsule and synovial membrane on the outer side of the joint also and to divide the lateral ligament on this side so that a fine elevator can be inserted on each side beneath the neck of the metatarsal bone The head of the bone is thus fully exposed and inspected It will be seen that only a portion of it enters actively into the articulation the inner part being denuded of cartilage and helping to form the external prominence This portion of bone is chiselled away thoroughly and any thickened tissue overlying it removed the rough bone is then smoothed with a file the joint cavity being carefully inspected to make sure that no chips of bone are left

behind, and the capsule of the joint and skin are then separately sutured

Excision of the head of the first metatarsal bone.—The operation is carried out as described above up to the point at which the head of the metatarsal bone has been brought fully into view This bone is then chiselled away with a fine osteotome on all sides until a new small rounded head has been shaped the amount of bone removed depends upon the severity of the deformity The gap left between the new head and the base of the phalanx must be sufficient to allow the toe to be brought into line without tension It is desirable, if possible, to leave a small portion of the surface beneath the

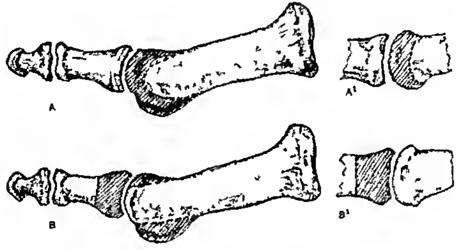

Fig 27 —Operations for hallux valgus

A Dorsal A¹ lateral view of operation for hallux valgus by limited excision of the head of the metatarsal bone B Dorsal B¹ lateral view of operation for hallux valgus by trimming the head of the metatarsal bone and excision of the base of the phalanx

head of the metatarsal which rests upon the sesamoid bones The cut surface of the bone is filed smooth The capsule of the joint and skin are then sutured (Fig 27)

In Mayo's modification of this operation the new metatarsal head is covered with a fascial flap which has been dissected backwards and left attached to the neck of the metatarsal bone This introduces a complication in the operation which seems to make no difference to the eventual result The insertion of this flap has been abandoned by most surgeons

Excision of the base of the first phalanx.—The preliminary stages of the operation are the same as those last described but the incision through the capsule of the joint must be carried forwards over the first phalanx, just internal to the long extensor tendon Narrow elevators are passed round the middle of the phalanx on the inner and outer sides, the phalanx is lifted up, and is cleared of attachments completely In doing this the attachments of the short muscles on the plantar aspect have to be divided, and care must be taken to avoid

division also of the long flexor tendon About three-eighths of an inch of the base of the phalanx is then removed with a Gigli s saw or with a fine finger saw The non articular part of the head of the first meta tarsal is removed together with any osteophytes the metatarsal head being trimmed down to a rather small size the articular cartilage covering its extremity being left intact The deep tissues and skin are then sutured

After any of these three operations the patient may be allowed to walk on the foot as soon as the wound has healed that is in about ten days It is advisable to support the toe and the transverse arch of the foot with adhesive strapping from the time that the wound is healed for about two months One piece of strapping is attached to the inner side of the toe and drawn backwards along the inner side of the foot to hold the toe abducted A second piece is passed circularly around the foot immediately behind the heads of the metatarsal bones

As hallux valgus is commonly associated with some clawing of the outer toes this should be treated by suitable massage manipulations and exercises after the operation The second toe is sometimes found to be dislocated at the metatarso-phalangeal joint having been lifted up by the big toe If this condition is present it should be treated by excision of the base of the first phalanx of the second toe at the time of the hallux valgus operation

OPERATIONS FOR HAMMER-TOES

Hammer toes are not always of the same anatomical variety The true hammer toe affects chiefly the second toe and consists of an acute flexion of the first interphalangeal joint The skin beneath this joint is usually shortened so that straightening is prevented by its con traction as well as by contraction of the ligaments of the joint There is often a corn and bursa on top of the joint

When several toes are affected the condition is usually one of claw toe rather than hammer toe By this is meant that there is a contraction of the first interphalangeal joint of each toe but the skin beneath is not appreciably shortened This condition is usually associated with pes cavus of greater or lesser degree In both hammer toe and claw toe the metatarso phalangeal joint is hyper extended and may actually be subluxated

Other deformities met with are

1 Fixed flexion of the terminal phalanx
2 Lateral deviation of the distal part of one or more toes inwards

For all these conditions the best operative procedure (if operation is necessary) is Higg s spike operation (Fig 28) which produces a stiff fixed joint

In carrying out this operation on a typical hammer toe an elliptical incision is made removing the corn and bursa and exposing the head

of the first phalanx The extensor tendon may be lifted aside or cut away its ends will not retract, but unite of their own accord after the wound is sutured The head of the first phalanx and the distal half of its shaft are cleared completely with a knife and rugine With a small pair of bone cutting forceps the head of the bone is cut away on each side, so that the distal end of the phalanx terminates in a spike The articular surface of the second phalanx is then drilled, either with a special pointed burr or a fine gouge The spike is impacted into the hole thus drilled and the skin sutured The removal of an elliptical piece of skin on the dorsum shortens this surface of the toe and holds the spike in position

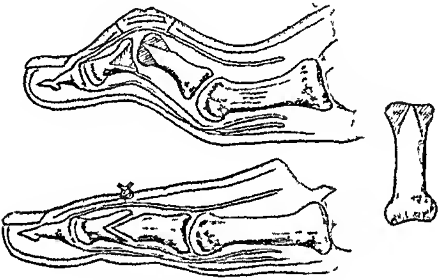

Fig 28 —The spike operation for hammer toe

No splint is necessary when the stitches are out, the joint may be protected with simple strapping until it has had time to consolidate At the time of the operation the first phalanx should be forcibly flexed upon the head of the metatarsal bone

This operation may be used for all the above conditions with appropriate modifications e g in a lateral deviation the elliptical incision is situated upon the outer convex aspect of the joint The only exception is that in some cases of flexion of the terminal joint, amputation through this joint is simpler Also, in bad clawing of the little toe in an adult, it is sometimes impossible to get the toe on the ground, and it is then simpler to amputate it When a hammer toe of the second toe co exists with a bad hallux valgus deformity, it is useless to straighten the second toe if the big toe is left deformed, as there is no room for the second toe to lie in its proper line When this complication exists, an operation for hallux valgus should be combined with that for hammer-toe

INGROWING TOE-NAIL

If an *ingrowing toe-nail* cannot be kept under control by simple measures it may be treated by avulsion of the nail, by Willett's operation or by removal of the whole nail bed

Avulsion of the nail is carried out under general or local anæsthesia one blade of a flat-bladed pair of forceps is pushed well down under the nail which is grasped twisted free at the sides and then pulled out from its root Unfortunately the new nail is likely to grow in the same way as the old one and recurrence is common

Willett's operation.—This aims at the production of a flat scar along that side of the nail which tends to grow in A tenotome is passed in at the side of the base of the nail, deep to the skin, and undercutting it to a width of half an inch The tenotome is then worked forwards to beyond the tip of the nail, thus raising a flap of skin half an inch wide along the whole of the nail margin, this flap is cut off at its base and the raw area allowed to heal by granulation

Extirpation of nail-bed.—If the nail bed is simply extirpated by dissection, a raw area is left which has to heal by granulation and which may leave a bad scar The best method is to carry out a formal amputation of the last phalanx of the toe The absence of this phalanx does not in any way weaken the foot Some surgeons prefer to remove the nail bed and shorten the toe by removing only the distal half of the phalanx, but this does not appear to have any advantages, and complicates the operation by dividing bone in what is often a septic field

OPERATIONS FOR WEBBED FINGERS

Operative treatment for webbed fingers must be planned to suit each individual case The method to be adopted will depend upon the width of the web whether it extends down to the extremity of the fingers or stops short of the region of the nails, whether it involves the nails, and whether the bones are fused When there is a partial or complete fusion of the bones, it may be advisable to leave the condition untreated, as operation is likely to lessen rather than improve the usefulness of the hand

It must always be remembered that the object of the surgical treatment is to make the hand both sightly and useful Operation must be planned so that all raw surfaces are covered with ample skin of sound texture, which is not adherent to bone or tendon, and which is not badly scarred but is as supple as possible For this reason, in flap operations the skin must cover the raw area without tension Thiersch grafts are unsuitable and, as a general rule, raw areas should be covered by pedicle grafts although Wolff grafts containing the whole thickness of the skin may be used on the lateral aspect of the fingers when they are in contact with subcutaneous fatty tissue only and not with bone or tendon Many of the operations usually described

look well in diagrams but are impossible in practical application Children stand pedicle grafting very well and cease to be worried by the fixture of the hand to the abdominal wall after a few days

It is wise to postpone operation on webbed fingers until the child is about four years old By so doing the actual operation is rendered simpler and the child is more easily managed The two methods described below will suffice for most of the cases suitable for operation

1 Wide webs.—When the web is sufficiently wide to enable the fingers to be held apart right down to the cleft, the skin of the web will be sufficient without the addition of a graft But such cases are rare There is a temptation simply to split the web vertically and suture each half, but this method will almost certainly end with the

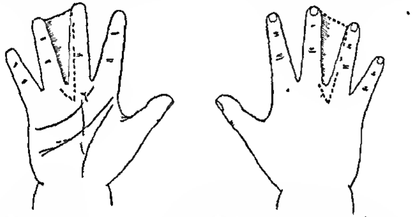

Fig 29—Webbed fingers Operation for a wide web The flap taken from the dorsal surface is wrapped around the middle finger, that taken from the palmar surface around the ring finger Both are sutured accurately into place

web fusing again in its proximal part, and the scarring will interfere with mobility

In the middle and ring fingers, incisions on the dorsal and palmar surface are made as in Fig 29, the skin of the web being thus split into a palmar layer attached to the ring finger and a dorsal layer attached to the middle finger Proximally each flap includes V-shaped portions, that on the dorsal surface extending proximally well back on to the margin of the head of the fourth metacarpal, that on the palmar surface need not be quite so large The dorsal flap is then wrapped round the middle finger, the apex of the V is first fitted into the corresponding point on the palmar aspect and sutured there with fine interrupted sutures of silkworm gut, the rest of the flap being sutured in a similar manner The palmar flap is then sutured round the ring finger in the same way, and finally the two flaps are sutured to each other at the cleft between the fingers The skin on the dorsal aspect is loose and extensible, and this should allow the flaps to be fixed without tension If there is tension on the flaps the case has been misjudged and should not have been

treated by this method Dressing is kept packed well into the cleft and the stitches are only removed when healing is complete

2 Close webs.—When the web is close, all the skin available should be used to cover one of the fingers, the raw area left upon the other being covered by a pedicle flap The skin is taken from the dorsal surface of the longer finger to cover the other In the case of the index and middle fingers a flap is raised from the dorsal surface of the middle finger as shown in Fig 30, it includes a V shaped portion proximally similar to that used in the previous operation Anteriorly an incision is made vertically in the line between the fingers, the cut should extend through skin only and the fingers should be

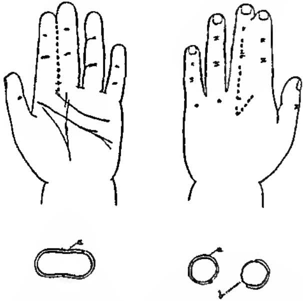

Fig 30—Webbed fingers Operation for a close web The flap taken from the dorsal surface is (a) wrapped around the index finger and sutured into place The raw area (b) left on the middle finger is covered by a pedicle graft

separated well down into the cleft by blunt dissection This involves less risk to the digital nerves and vessels The flap is then wrapped round the index finger and sutured anteriorly, the V-shaped portion being first fitted down into the cleft The hand is then laid upon the abdominal wall in an easy position and a flap marked out long enough to cover the whole length of the raw area on the middle finger without tension This is dissected back, without fat, just far enough to enable it to be sutured in place It must be sutured accurately to the whole length of the skin margin on the dorsum of the ring-finger, the proximal edge must be sutured to the edges of the flap on the index finger in the depth of the cleft, and the distal edge must be sutured to the skin margin on the ring-finger where it extends round near the nail The palmar aspect is thus the only part which is left unsutured It is useless to attempt to suture the raw area

on the abdominal wall Dressing is packed well down into the web and between the fingers and the abdominal wall The arm is secured in position by wide adhesive strapping passed round the forearm and over the shoulder and round the arm and circularly around the chest The surgeon should fix these while the fingers are exposed as he can then see that the circulation is not interfered with The dressing should be changed every few days At the end of three weeks the skin flap is separated from the abdominal wall the skin margin on the anterior aspect of the middle finger is cut away to a clean edge and all granulation tissue is removed carefully from the raw area and from the under surface of the flap The flap is then carefully sutured into place The abdominal wound may be sutured after excision of the granulation tissue and skin margins or it may be left to heal by granulation

OPERATIONS FOR DUPUYTREN'S CONTRACTION

Two methods are used for the *correction* of Dupuytren s con traction —

1 Subcutaneous operation —This is especially indicated in cases of moderate severity in which there are a few tight bands and the skin is not very deeply puckered It may also be used in very severe cases in which the fingers are tightly flexed into the palm so that at any rate in the first instance an open operation cannot be performed because it is impossible to get proper access to the part This leaves the open operation as that usually advised in fairly severe cases which have however not reached the extreme degree of development Actually the choice between a subcutaneous and an open operation depends largely upon the individual surgeon some surgeons preferring one some the other

The subcutaneous division is carried out by inserting a fine bladed tenotomy knife under each hard band in turn choosing the intervals between the puckers in the palm and dividing the bands The teno tome is also passed on the flat beneath each deep pucker in the skin so as to separate the skin from the fascial bands to which it is adherent at these points A number of punctures must be made the palm and finger joints being gradually flattened out It may not be possible to correct the whole of the deformity at one sitting it may be necessary to wait until the first series of punctures has healed and then after two or three weeks to divide those bands which have escaped at the first operation A metal splint with separate pieces for each of the affected fingers should be fixed upon the hand at the time of the operation worn continuously for six weeks and for a further six months at night only

2 Open operation —Two varieties of open operation may be performed In the first one or more vertical incisions are made over the contracted bands extending as far up the palm and down the finger as is necessary Through these incisions the palmar fascia is

exposed and the whole of the indurated tissue is dissected out systematically It is usually necessary to dissect sufficiently deeply to expose the sheaths of the long flexor tendons in order to make sure that the whole of the affected fascia is removed

This operation may be impossible in severe cases (1) because the fingers are too greatly flexed to allow access to the palm and (2) because the skin is too contracted to permit its subsequent suture In the first case a subcutaneous operation at any rate as a preliminary is advisable In the second case it may be advisable to make a V-shaped incision into the palm cutting through the skin and fascia and to unite this incision as a Y In using this latter method the affected bands of fascia may be removed or may simply be divided The use of the splint in the after treatment is not so necessary after the open operation as after the subcutaneous method if the removal has been thorough

ISCHÆMIC CONTRACTION OF THE FLEXOR MUSCLES OF THE FOREARM

In ischæmic contraction the fibres of the affected muscles have undergone an aseptic necrosis and have disappeared being replaced by fibrous tissue Usually the pronator radii teres flexors of the carpus and flexores sublimis and profundus digitorum are thus affected and the forearm is held in a position of pronation with the wrist and fingers flexed There is often in addition partial involvement of the median and ulnar nerves so that the sensation in the hand is imperfect and the intrinsic muscles may be involved

Correction of the fixed deformity may be attempted by splinting or by operation but it is a mistake to expect a considerable functional recovery Very often there is little or no muscle substance left so that if the fingers and wrist are straightened they are incapable of active flexion Paralysis of the intrinsic muscles of the hand of course also seriously interferes with the chance of good functional recovery

Gradual correction of the flexion deformity by splinting is possible in cases of recent onset but this method is of little value in old standing cases Lengthening the tendons of the affected muscles will correct the contraction but any remaining power will certainly be sacrificed by this method The best method of attempting to correct the deformity and at the same time to retain any power which remains is by detaching the affected muscles from their origins

A long incision is made from the internal supracondylar ridge down the inner aspect of the elbow and forearm half way to the wrist The common flexor origin is detached from the internal epicondyle the ulnar nerve is isolated and the whole of the front of the ulna is then stripped of muscles working from the inner border The attachment of the brachialis anticus to the coronoid process should alone be left If the fingers and thumb still cannot be straightened completely a second incision is made on the outer side of the anterior aspect of the

forearm between the supinator longus and the biceps tendon, the musculo spiral nerve at its termination retracted to the outer side and the tendon of the biceps muscle followed down until the radius is reached The attachment of the flexor sublimis digitorum to the anterior oblique line of the radius can then be separated and below this the flexor longus pollicis detached from the anterior aspect of the bone

After suture of the wound, the band is fixed on a splint with a moderate degree of extension of the wrist and fingers the splint is retained for six weeks but removed daily for manipulations and active movements as soon as the wound is healed

This operation improves the appearance of the hand considerably, but the degree of improvement in function depends on the amount of muscle which has escaped destruction

CHAPTER IV

OPERATIONS ON JOINTS

By P JENNER VERRALL

Introductory—During the War of 1914–18 and the decade which followed it the mass of clinical material and the need for surgeons to devise means of restoring to functional and wage-earning efficiency joints injured by wounds provided an unprecedented field for surgical experiment Some of these procedures have stood the test of time and some have not Only those measures which have reached an established position will be described

Only a few years ago the majority of joint operations were for the eradication of tuberculosis but these are now rarely called for and whereas at that time the opening of an aseptic joint was approached with diffidence the increased efficiency of asepsis has so widened the scope of joint surgery that in suitable surroundings and provided with modern equipment the surgeon need no longer hesitate

Arthroplasty in spite of many brilliant results has not on the whole given the satisfaction that the accurate technique bestowed upon it led surgeons to expect while they have increasingly realized that a joint ankylosed in good position gives a far more useful limb than one which has perhaps 5 degrees of painful movement and the possibility of lateral instability or recrudescence of disease The mechanical difficulty of intra articular arthrodesis where the necessary removal of opposing cartilaginous surfaces leads to bad co-aptation has led to the advance in methods of extra articular fixation

The resistance of the peritoneum to contamination was underestimated for years We now know that this is not true in the same *degree for synovial membranes* the opening of an aseptic joint must therefore still be regarded as demanding minute attention to aseptic detail

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

Morphology—The earliest sign of joint formation in the primitive limb-bud is the appearance of a thickening of the mesenchyme between the masses which will subsequently develop into bones At first this is a simple joint plate and in *synarthroses* all the intervening material persists In amphiarthroses however such as the intervertebral discs and symphysis pubis there is early formation of a cleft which becomes filled with a mucoid substance In diarthroses a full cavity develops which may be multiple in those joints where there are

intra articular structures the latter representing a persistence of the intervening substance between two separate cavities The surroundings of the cavity form two layers of which the outer becomes the primitive capsule and the inner the early synovial membrane In the course of development of diarthroses this primitive capsule becomes thin to vanishing point on those aspects of the joint on which no ligamentous strain is imposed and the range of movement is checked by other means while other parts become thickened to form special ligaments In many cases these thickenings are morphologically detached portions of muscles which originally crossed the joint and have in the course of evolution ceased to do so gaining new insertions and leaving the distal part of their tendons as ligaments The knee and shoulder afford good examples of this In the former the original capsule is almost non existent the anterior capsule consisting of the tendons of the vasti the ligamentum posticum Winslowii being a development of the semi membranosus and the internal and external lateral ligaments being detached tendons of the adductor magnus and peroneus longus respectively In the shoulder the coraco humeral ligament represents the upward extension of the pectoralis minor Ligaments may also develop from the sheaths of muscles e g the ilio femoral from the iliacus on the inner and the gluteus minimus on the outer side These specialized structures indicate exactly where strain may be expected and their integrity must be respected in reconstructive operations

Component parts of joints—The articular ends of the long bones are formed of spongy bone which as the joint is approached becomes much denser and a thin plate is formed Over this lies the articular cartilage hyaline with no perichondrium or covering of synovial membrane The elasticity of this cartilage is of primary importance as a shock absorber and no other substance can replace it in this respect For this reason and also because it is a non expendable tissue i e one which is never fully replaced after injury the greatest care must be exercised to avoid damaging it in the conservative surgery of joints Such operations as that of Nikoli on the shoulder or the elevation of the external articular surface of the femur to prevent outward dislocation of the patella have this definite disadvantage

Articular cartilage contains no blood vessels and no nerves its nutrition being supplied partly from the underlying vascular bone but mainly from the synovial fluid When a joint is injured either a synovial fringe becomes temporarily attached to the lesion or a pannus grows in from the vascular periphery By this means repair by fibrous tissue is achieved Early movement of the joint during the process destroys this delicate tissue it must be constantly re formed and recovery is delayed Failure of these temporary structures to disappear when they are no longer needed is a potent source of intra articular adhesions

Fibro cartilages may be intra or extra articular and may represent either the remains of a primitive division of the joint or the vestiges of structures that have vanished during evolution e g that of the sterno-clavicular joint Until recently it was thought that they had no nerve supply but the contrary has now been clearly proved and sensory nerve endings can be shown microscopically in special preparations

The synovial membrane lines the interior of the joint with the exception of the articular cartilage and fibro cartilages It is composed of vascular connective tissue and the synovial fluid produced from it is a transudate and not a true secretion Until recent years it was considered a valuable non expendable structure but it has been shown both from animal experiments and by experience in human surgery that it is completely re-formed after surgical removal When therefore it is pathologically thickened as in cases of arthritis its removal is indicated at the same time as other surgical methods to improve the mechanical factors of the joint The synovial membrane is extended into the interior of joints in the form of fringes which may be much hypertrophied in certain arthritic conditions

The synovial membrane its fringes and the capsule and ligaments of the joint are freely supplied with both vessels and nerves the latter being myelinated and the purveyors of pain and the proprioceptive sensations of position The end organs are mostly Pacinian corpuscles but in the ligaments there are structures analogous to the muscle spindles and neuro tendinous end organs found in the locomotor system The central control for this system lies in the cerebellum

Mechanics of joints —In joints such as the sacro-iliac or symphysis pubis very little movement is contemplated but the small range permitted is of primary importance The surfaces are irregular and the integrity of the joint depends on strong ligaments in which a certain amount of elastic tissue is incorporated These joints are therefore shock absorbers and are most efficient during the period of active life They tend to become fixed by bony ankylosis when increasing age brings this period to an end The joints of the pelvis are affected in the female by the considerations of parturition It is well known among cow keepers that the time of calving can be predicted by palpation of the sacro iliac joints and the softening of their ligaments which facilitates birth In human beings the same process takes place during the last two months of pregnancy

During the puerperium involution of the joints takes place premature activity tending to produce laxity and consequent pain As with the uterus subinvolution is automatically cured by a further pregnancy with a more carefully managed puerperium In chronic cases extra articular fixation will give a certain cure

The stability of diarthroses depends in such situations as the hip partly on the cohesion of surfaces and the effect of atmospheric pressure but in the looser joints these factors are negligible and stability depends on the specialized ligaments and above all on muscle tone

The lateral ligaments are so placed that the distance between their upper and lower attachments remains constant for all positions of the joint The importance of muscle tone is greatest in the shoulder, where the necessity for free mobility has led to a diminution of the actual joint surface Its early restoration is highly important in all reconstructive operations

Movement of a joint is produced by leverage, and for this to be effective there must be adequate muscle-power and good muscle tone, a firm fulcrum and a not disproportionate weight In the shoulder the fulcrum is normally unstable, and in reconstructive operations the preservation of maximum length of the humerus is of paramount importance, as the power of the deltoid decreases with the shortening of its lever Where possible, as in the elbow or knee, removal of bone should take place mainly on the proximal side of the joint so as to avoid bony contact and preserve the levers It is also important that the efficiency of flexors and extensors be evenly balanced as inequality of potential leads to instability The familiar Trendelenburg test illustrates well the principles of leverage It is not, of course, a pathognomonic sign of dislocation, it merely indicates that the abductor muscles of the hip are inadequate, and it can be equally well elicited in some cases of poliomyelitis or infantile coxa vara. The integrity of the lever is at fault, either through loss of a stable fulcrum or through the weakening of controlling muscles by disease, or by the approximation of their origin and insertion

The range of movement of diarthrodial joints is never checked by bony apposition except the temporo-maxillary by meeting of the teeth Even in the elbow, where the ulna might be supposed to impinge on the olecranon and coronoid fossæ, soft tissue is interposed and the impact is not on the cartilage In most cases limitation of range is controlled by ligaments, as in the thigh by the opposition of soft parts or by muscle tension

TYPES OF OPERATION

Mobilization of joints by manipulation.—Although the knife is not used in this procedure, very definite skill is needed All orthopædic surgeons are quite familiar with this method, but others have regarded the mobilization of joints as in the province of the "bonesetter" The accusation that surgeons have sometimes performed open operations on cases that could have been cured by mobilization is as true as the statement that all "bonesetters" are frauds is untrue Certain "bonesetters" undoubtedly have manipulative skill, but surgeons must in addition, be capable of differentiating between cases curable by manipulative surgery and those which require open operation, and they must be able to carry out whichever method is indicated The surgeon must be acquainted with the normal range of movement of the joints in all directions, and must not omit to test this on the unaffected side, as the range of certain joints, notably the wrist, differs considerably in different individuals The sensation of

resistance due to different causes—bony ankylosis bony block or adhesions—is acquired only by practice as is dexterity in mobilizing a joint with firmness and the minimum of effort It is impossible here to detail all the types of case suitable for mobilization, suffice it to say that mobilization is contra indicated—

(1) Where there is firm ankylosis bony or fibrous
(2) Where movement is limited by the impingement of one bony mass on another so called ' bony block
(3) Where stiffness is due to the destruction of joint surfaces
(4) Where there has been severe sepsis around the joint

Error can be avoided by a careful consideration of present and past symptoms and of good skiagrams The most suitable cases for mobilization are those of peri articular extrasynovial adhesions of traumatic origin An apparently complete range of movement does not exclude adhesions as these may be ruptured only on forcible movement to the extreme range possible under anæsthesia Careful study of the mechanism of joints will show that many movements occur, such as the up and down movement of the humeral head on the glenoid and rotations in the knee, which are not under normal muscular control and it is these which are in imperative need of restoration by manipulation All infective cases must be approached with the greatest caution and mobilization can only be considered when lapse of time and an exhaustive investigation have excluded even the faintest suspicion of latent sepsis

General method—Full anæsthesia is required for complete relaxation Some surgeons maintain that nitrous oxide is insufficient and this is true for the spine hip and shoulder but when properly administered it suffices for other joints as a period of relaxation always occurs and can easily be noted with experience The pre administration of basal anæsthetics such as avertin or nembutal is contra indicated as they seem to make it much more difficult to obtain muscular relaxation by subsequent inhalation anæsthesia Injections of evipan for simple cases and of pentothal for longer manipulations have proved ideal Adjacent bones susceptible to fracture must be protected during the operation by splints such as two metal gutters or a piece of *Gooch splinting* firmly bandaged on The various movements of the joint are performed seriatim with steadily applied force and in most cases to the full degree no jerky movements are permissible Where however the adhesions are very firm the trauma of a complete mobilization may be too severe and the operation can then be done in two or more stages

After the operation if few adhesions have been ruptured massage faradism and exercises are employed as soon as the patient has recovered consciousness if there has been extensive trauma it is better to bandage the joint firmly and evenly over a thick pad of wool for twenty four hours before further treatment is commenced No splint is required Pain after the operation is unusual if the

manipulation has been complete, and in any case should be of short duration, and range of movement should be maintained or increased Prolonged pain and diminishing range are indications for rest All active movements are encouraged, and assisted active movement of the joint should be carried out through the full range daily The pain felt during the early days of treatment is soothed by massage, heat, and sedative electricity (anodal galvanism) Gymnastic exercises will complete the cure For the hip and shoulder, an assistant is required to steady the pelvis and scapula respectively, and the movements of hyperextension and rotation must not be neglected In treating the knee, flexion must be full, as it frequently happens that only at this point are adhesions ruptured and the movements of internal and external rotation must be remembered The temptation to mobilize obstinately stiff fingers is great but experience teaches that, while small degrees of disability are well treated by this method, fingers whose mobility is seriously limited are intolerant of force, and require gradual methods

Aspiration of a joint may be employed for one of two purposes (*a*) Diagnostic —Where a joint is distended with fluid and there are signs, local and general, of inflammation, the insertion of a large bore needle into the joint cavity, with full aseptic precautions, and the removal with a Record syringe of fluid for bacteriological and cyto logical examination is of great value (*b*) Therapeutic —After severe manipulations and after operations performed with a tourniquet where the bandage has been inadequately applied or prematurely removed, a hæmarthrosis may occur Early aspiration of the blood while still fluid, followed by careful rebandaging, will hasten recovery and prevent adhesions In extremely low grade infections, repeated aspiration may avoid arthrotomy Irrigation may be performed by this method but the fluid must be normal saline or a non irritant antiseptic, the introduction of strong antiseptics into a joint is useless or worse The sites for aspiration are in general similar to those for arthrotomy

Arthrotomy consists in the exposure and opening of a joint, and may be either an operation in itself or the preliminary to further measures

Erasion —The joint is opened diseased synovial membrane dis sected away and foci of disease in the bones curetted This operation was formerly practised for tuberculosis but has become almost obsolete, as conservative measures produce at least equally good results Many surgeons now perform a similar operation in arthritis deformans, with beneficial results It has been found that very free synovectomy is permissible, as the membrane is re-formed These operations are therefore tending to become more and more extensive

Excision —In excision the whole joint is resected, without any effort to reconstruct it For tuberculosis every stage between the simplest erasion and an extensive resection has been performed, but

these operations will now be required but rarely Each case must be judged on its merits, but some indication will be given later for the treatment of individual joints Opinions differ on the value of primary excision for injury The emergency surgeon is concerned only with the saving of life or limb, and must provide drainage and arrest sepsis at all costs The reconstructive surgeon, on the other hand, while deploring any unnecessary sacrifice of bone, is not justified in criticizing adversely what have often been operations of necessity

Arthroplasty.—This is essentially an artificial pseudarthrosis, the shape of the joint surfaces being reconstructed and an attempt made to produce a bursal substitute for the original joint cavity Several methods are described later, but the ingenuity of the individual surgeon must be allowed full play Certain conditions are essential to success —

1 *The removal of exactly the right amount of bone*—This is still a matter of controversy, but error is usually on the side of removing too little

2 *The prevention of subsequent callus formation from the cut ends*—With this object in view the raw surfaces should be filed smooth and hammered flat Horsley s wax was advocated by Sir Harold Stiles and in his hands was successful, but the method has proved less satisfactory than the interposition of fascia, and is rarely used now

3 *The interposition of a flap of fascia*—Most surgeons employ a flap from the subcutaneous tissue in the vicinity or from the fascia lata of the thigh Experience has shown that no advantage is gained by the retention of a vascular pedicle Both the opposing surfaces may be thus covered, but one layer is usually sufficient Accurate apposition is obtained by the use of interrupted catgut sutures, or a purse string suture may be used to fix the fascia as a bag over the bone-end

4 Great attention should be paid to *hæmostasis*, and no drainage should be used

5 A true mental picture of the condition of the new joint will guide the *after treatment* All forced movements will obviously risk the destruction of the protective barrier, and the tendency with all surgeons now is to delay movement longer and longer No passive movement should be used at any time Ten days after the operation the stitches are removed and the patient asked to move the joint (with a large joint the weight of the limb must be supported by the surgeon) If there is voluntary movement, however slight, the prognosis is good, the joint should be immobilized for a further two weeks at least, and the muscles then re-educated, without overstretching, on ordinary orthopædic principles

Arthrodesis.—This operation has for its object the abolition of movement in a joint, and may be performed by intra- or extra articular methods or by a combination of the two In the former case the surgeon aims at obliterating the joint cavity and substituting firm

union between the joint surfaces. Where the bone-ends are relatively undamaged, nothing more is needed than the removal of cartilage and the apposition of the surfaces; but if much bone has been lost, more elaborate measures will be required. In the latter he constructs, by grafting, a bridge of bone uniting the contiguous bones around the joint. Fixation is indicated where a joint has ceased to be under muscular control, either through incurable paralysis of the muscles or extensive loss of bone, and in certain cases of arthritis where pain is intolerable and uncontrollable by other means.

Ankylosis was divided by Thomas into *unsound*, where disease is active and deformity progressive, and *sound*, where the reverse is the case. Unsound ankylosis calls for fixation. Sound ankylosis, if in bad position, calls for operation; if it is in good position, operation is only indicated if a mobile joint is necessary or desirable.

The best position for ankylosis is that in which all diseased joints should be treated, and which will produce the most useful limb should ankylosis result, as follows:—

Shoulder.—45°–90° abduction (the younger the patient the greater the angle, as the scapula is potentially more mobile), and 20° flexion in front of the coronal plane, the latter angle facilitating the movement of the scapula round the chest-wall.

Elbow.—The requirements of the patient must be considered. In most cases 90° will be convenient. If both elbows are ankylosed, the right should be more and the left less than a right angle, the left being required to carry food to the mouth with a fork and the right to cut up the food.

Forearm.—Midway between pronation and supination.

Wrist.—Dorsiflexion to a moderate degree is essential to the preservation of an efficient grip.

Hip.—Slight abduction and external rotation. Some surgeons advise full extension, and this is certainly advisable when there is any doubt of the permanency of the ankylosis. It must be noted, however, that when ankylosis is fixed and permanent, flexion to 30° gives a better gait and permits the patient to sit with more comfort. The consequent lordosis is amply compensated by these advantages.

Knee.—Full extension. Many surgeons advocate 135°, as rendering stairs more easy, but the same objections arise as in the hip when there is doubt of the solidity of the ankylosis.

Ankle.—Experience shows that 5° of dorsiflexion is better than a right angle, though the latter is advocated by some surgeons.

OPERATIONS IN VARIOUS CONDITIONS

Penetrating wounds of joints.—The following is a brief synopsis of the lines of treatment based on the directions of the late Sir Henry Gray to Casualty Clearing Stations in the War of 1914–18.

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1 Where it is doubtful whether there has been actual penetration of the synovial membranes, the joint should be immobilized and an

expectant attitude adopted Any effusion is aspirated and the fluid tested bacteriologically If organisms are found the wound should be excised and the joint washed out with a warm non irritating antiseptic and drained for twenty four hours Simple hæmarthrosis is best treated by incision lavage with saline solution and immediate suture as by this means subsequent adhesions may be largely avoided

2 Where penetration is certain the wound track should be cauterized in its external part and at once carefully excised in one piece the edges of skin muscle capsule and bone being freely removed together with the foreign body if present and the joint washed out with saline or flavine The capsule is sutured and a drain reaching down to this point left in the wound for a few days the joint being immobilized until all danger is past

3 Extensive comminution of bone will necessitate the removal of loose fragments and free drainage no more bone being removed than is necessary If life is in danger no hesitation should be felt in opening the joint freely or excising it and employing continuous irrigation as by this means amputation may frequently be avoided

Operations for tuberculosis—The comparative frequency of excision and erasion for this disease in times past was due not so much to lack of knowledge of the value of conservative surgery as to lack of efficient institutions in which this could be carried out and operation was done as a *pis aller*

In most parts of the British Isles there is now good provision for the treatment of tuberculous children and no child should be subjected to excision of a joint except in the rarest circumstances Provision for adults is however deficient and considerations of time and occupation may still indicate radical operation especially in the knee joint

It must be understood that this refers to tuberculosis of the joints themselves para articular tuberculosis being still an indication for operation

Even when operation is performed careful after treatment by diet climate and heliotherapy is still strongly indicated *

Thus in children intra articular operations are entirely contra indicated owing both to the risk of impeding growth by interference with the epiphyses and to the excellent results of conservative treatment Operative extra articular fixation though permissible in children is better suited to adults Where conservative measures have failed or there is extensive destruction of the joint multiple sinuses and actual or impending amyloid disease amputation is far better than excision especially in the lower limb

Operations for arthritis deformans—More and more are the various diseases loosely grouped under this name coming within the range of surgical methods Joints thus affected have a very low resistance to outside infection and the greatest aseptic care is needed in operating on them It is obvious that much attention should be

* See also Conservative Treatment in Surgical Tuberculosis " p. 48

paid to eradication of the toxic cause and to arrest of the progress of the disease before any reconstructive methods are employed

Operative treatment is still in the experimental stage, but the following procedures are well worthy of trial

1 Simple arthrotomy, with evacuation of fluid and the admission of air into the joint Aspiration with the injection of oxygen is an alternative

2 Arthrotomy and free lavage of the joint with ether

These two methods are most successful in arthritis of intestinal origin, whether typhoid, dysentery, or bacillus coli

3 Free opening of the joint with removal of hypertrophied villi, thickened synovial membrane, loose bodies and obstructing osteophytes This is an old method but it has been revived after a period of oblivion, and promises to give good results Very free incision and access to the joint are essential Even in cases seen before the disease has progressed far, but where the symptoms or skiagrams show that some one object is impeding function, a simple operation for its removal is justifiable, as by improving the function of the joint the cure is assisted

For these operations the selection of suitable cases is essential, as no good result is possible without the co operation of the patient, who must be prepared to persevere with an after-treatment that is often painful

4 Arthrodesis is indicated where milder methods have failed and pain is severe, due attention being paid to the age of the patient

5 Excision is often advantageous in younger patients with severe disease but arthroplasty will undoubtedly prove to be the ideal method when technique has been perfected It is especially suited to atrophic cases, where there is less tendency to ankylosis, as the bone-ends are hard and sclerotic and there is less osteogenesis

OPERATIONS ON INDIVIDUAL JOINTS

Temporo maxillary Joint

Operation on this joint is occasionally indicated in cases of inability to open the mouth, due, it may be, to dislocation of the condyle or of the interarticular fibro-cartilage, or to arthritis In dislocation, attempts will have been made to reduce it by manipulation, these may fail, and it will then be necessary to perform an open operation for reduction In arthritic cases, where possible, excision of the condyle is to be preferred to Esmarch's operation on the horizontal ramus, but excision may be inadvisable owing to cicatrices

Technique.—An incision is made, 1 in in length, either horizontally along the lower border of the zygoma on a level with the tragus, or preferably inclining upwards and forwards from that process (Fig 81)

The temporal branches of the facial nerve, which run parallel with the latter incision, are drawn to either side, and the parotid gland

downwards and backwards The masseter fibres are separated from the zygoma with an elevator, the capsule exposed and a vertical incision made into the joint A displaced fibro-cartilage is either sutured into place or removed The condyle if dislocated is either levered back into position or cut off with bone forceps or a Gigli saw Where there is partial or total ankylosis from arthritis the joint is mobilized with an elevator or gouge the external pterygoid insertion divided and the condyle levered out and cut off the fibro cartilage being left behind if possible and the periosteum removed with the bone In cases of actual bony ankylosis with total destruction of the joint there may be no sign of the condyle It is then necessary to excise enough bone to allow the easy introduction of the tip of the forefinger If this

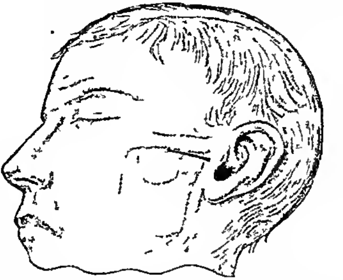

Fig 31 —Line of incision for operation on the temporo maxillary joint.

removal does not permit full movement the same operation will be required on the opposite side and must be carried out at the same sitting

After-treatment consists in early movement and probably, forcible movement under gas on two or three occasions Arthroplasty has little advantage over simple excision as the residual fixity is largely due to peri articular structures

A transient facial palsy is not uncommon after the operation

Sterno clavicular Joint

Excision.—Tuberculosis of this joint, which is not uncommon calls for early excision owing to the difficulty of conservative treatment and the risk of extension of the disease to neck or thorax once the limits of the joint are passed The operation is simple the end of the clavicle and all diseased tissue being removed

Fixity of this joint is more disabling than is commonly recognized

the mobility of the shoulder girdle being much impaired, and excision is indicated as soon as recrudescence of sepsis is no longer to be feared Unreduced dislocation may (rarely) call for excision when important structures are compressed by the displaced end of the clavicle

Acromio-clavicular Joint

This joint is occasionally the seat of unreduced dislocation and arthritis, frequently of traumatic origin Excision of the joint and wiring of the surfaces together has been performed but the results are not encouraging The condition is rarely very disabling, and is best treated by palliative methods In the reconstructive surgery of both this and the preceding joint, fascia lata sutures passed through the bones have proved most valuable

The Shoulder

Arthrotomy.—Simple arthrotomy is best performed by an anterior incision similar to that described below for excision

Indications (1) *Infective purulent arthritis*—A counter incision should be made either behind, below the lower fibres of the deltoid, or, as suggested by Burghard at the apex of the axilla, with the arm drawn upwards above the head A pair of forceps should be passed across the joint, and the incision made downwards upon their points in order to obviate injury to neighbouring structures

(2) *Loose bodies in the joint*—The removal of these is facilitated by rotating the humerus inwards and outwards and applying pressure in the axilla in order to bring the bodies to the surface

(3) *Lavage of the joint* with saline flavine, ether, etc (*see* p 115)

(4) *Irreducible displacement of the upper humeral epiphysis*

Excision. Indications—(1) *Tuberculosis*, where conservative treatment is unsuccessful

(2) *Destructive infective arthritis and epiphysitis*, where simple drainage is unsuccessful

(3) *Gunshot and other compound fractures and dislocations* with extensive destruction The objects are the removal of loose pieces of bone and drainage

(4) *Some cases of old-standing irreducible dislocation* Open operation should be undertaken for dislocation (*a*) where there is a co existing fracture of the humerus the dislocation being reduced and the fracture then treated by ordinary methods, (*b*) where previous attempts at reduction have failed, or an interval of six weeks has elapsed since the injury The anterior incision is used and, where possible, the head is replaced, a very determined effort being made to accomplish this before performing excision Tough adhesions and thickened capsule may need division, and the muscles attached to the tuberosities may obstruct reduction In the latter case the tuberosities should be chiselled off with their attached muscles, and replaced and pegged in position after reduction has been effected If reduction be impossible, excision or arthroplasty is indicated

(5) *Tumours of the head of the humerus* e g myeloma

Choice of operation —Three varieties of operation are recognized (*a*) by an anterior incision (*b*) by a posterior incision (*c*) by a deltoid flap

(*a*) *By anterior incision* —This is by far the most usual and useful The patient lies on his back with the arm slightly abducted the surgeon standing on the outer side of the affected shoulder An incision is made along the anterior edge of the deltoid beginning just below the coracoid process and extending 6 in down the arm (Fig 32) The interval between deltoid and pectoralis major is then opened up the cephalic

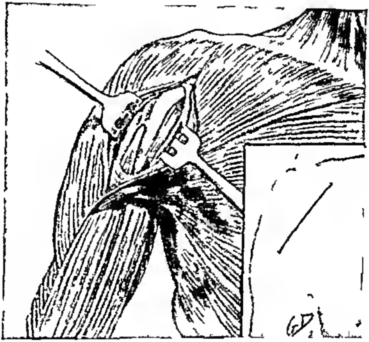

Fig 32 —Anatomy of anterior approach to shoulder joint. Inset, line of skin incision.

vein being retracted with the pectoralis A branch of the vein will need ligature at this stage The two muscles are widely retracted and the bicipital groove will then be seen in the bottom of the wound when the arm is rotated outwards The long tendon of the biceps is lifted up cleaned of tuberculous or other infective matter and carefully preserved and the capsule opened down to its lowest limits along the line of the groove The arm is then rotated inwards and the muscles attached to the greater tuberosity are carefully detached with a sharp curved periosteal elevator The arm is now rotated outwards and the subscapularis detached from the lesser tuberosity in the same way The bone is divided either *in situ* with a Gigli saw or preferably after dislocating the head of the humerus through the wound Although the former procedure disturbs the parts less the latter gives better access to the joint and enables the bone to be cut more accurately Dislocation is

effected by forcing the elbow upwards and backwards the soft tissues being well retracted and protected during the process Lane s elevators are very useful for this purpose The amount of bone removed will vary frequently the line of section will pass through the anatomical neck or the tuberosities in the case of tuberculosis other foci being removed with a gouge from the remainder of the humerus and the scapular surfaces and all other infected tissue dissected away It must be remembered that in no case must more bone be removed than is necessary for the purpose in hand An excision is intended for the cure of disease and reconstructive surgery is better left to a second operation the success of which will depend greatly on the retention of the maximum amount of bone The sharp inner margin of the divided humerus should always be carefully bevelled to avoid injurious pressure on the axillary contents Should it be found necessary to remove so much bone that there is no prospect of retaining a sound joint the further proceedings should be those of arthrodesis (p 122) unless it is proposed to replace the loss by a bone graft (p 278) The capsule and muscles are united by catgut sutures and the wound closed

The opinions of surgeons differ on the question of drainage If much oozing be anticipated it is well to drain by a posterior stab but drainage is best avoided

(*b*) *By posterior incision* —In this method which was devised by Kocher, the incision passes from the acromio clavicular joint backwards over the shoulder to the posterior axillary fold The acromio clavicular joint is opened and the base of the acromion divided and turned forwards with the deltoid Very good exposure and results are claimed for this method especially in tuberculosis which is likely to affect the posterior part of the joint but it has been little used in this country

(*c*) *By deltoid flap* —In this operation a transverse incision is made across the top of the shoulder The deltoid fibres are in part detached from their origin and in part divided and the muscle turned downwards This gives an excellent exposure and is chiefly applicable to cases of arthrodesis for infantile paralysis where no subsequent action of the deltoid is required (Fig 33) In other cases the muscle is re-sutured with No 8 chromic catgut and the arm kept in full abduction during convalescence

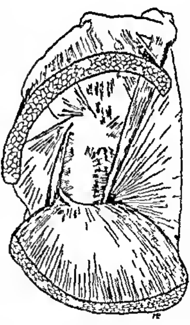

Fig 33 —Exposure of shoulder joint by deltoid flap

After-treatment —The limb is put up either on an abduction splint

or, preferably, in plaster in the position of ankylosis The application of plaster is much facilitated by performing the operation on a Hawley's table (Fig 34) To apply the plaster is not easy, but when properly done it is far the best method, and on the correctness of the application most of the results of the operation depend The chest and arm are enveloped in flannel or wool, and felt pads are bandaged in position, over the iliac crest and the root of the neck on the affected side, and under the opposite axilla (Fig 35) Three or four plaster bandages then cover in the arm and thorax, reaching well down to the hip Next, three plaster bandages are unrolled and made into strips 18 in in

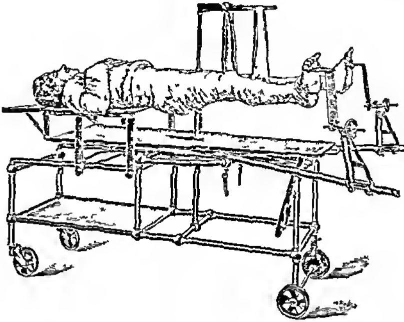

Fig 34 —Hawley's table for use in operations on shoulder and hip where plaster will be applied

The table is shown with the movable portion lowered leaving the pelvic rest in position, with gallows attachment for slings The movable bars serve for extension if required

length these are applied over the hip, across the shoulder, and around the axilla from chest to arm More bandages are applied until the cast is sufficiently thick A thin strip of metal is bent and applied so as to pass from mid-forearm along the arm to the axilla, down the chest to the hip, and up across the intervening space to the elbow, and fixed with an additional plaster bandage It is well to use bandages 8 in wide for the chest, and 6 in for the arm When set, the plaster is cut away so as to free the abdomen, a width of only 5 in (in adults) being left under the opposite axilla (Fig 36) Windows are cut over the wound or wounds If drainage has been employed the drain is removed in forty-eight hours If a splint has been used it should be replaced by plaster in ten days, if plaster, a new plaster will usually be required at this time, as that applied at the time of operation will have become stained and odoriferous

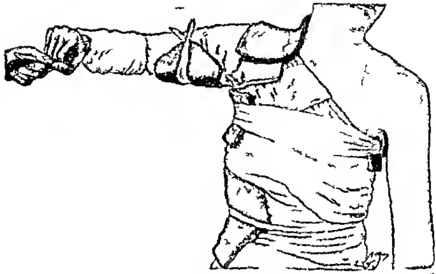

Fig 35 —Application of plaster to shoulder in abduction
First stage showing wool covering and felt pads in position

If ankylosis is desired immobilization must be maintained for three months the upper part of the plaster over the arm and forearm (Fig 36 A) being removed after three weeks for the purpose of faradism and massage to the muscles If movement is desired the plaster is removed from the shoulder in addition after three weeks (Fig 36 B) the appliance

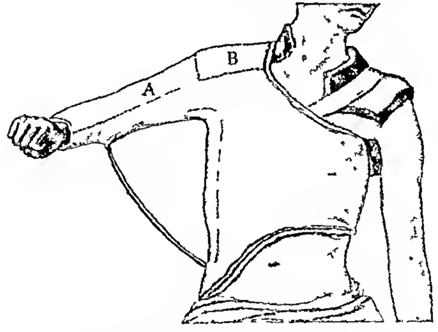

Fig 36 —Application of plaster to shoulder in abduction
Second stage showing completed plaster with metal arm-support The dotted lines on the arm indicate situations in which plaster should be subsequently cut away The padded webbing on the opposite shoulder is also shown

being kept in place by the substitution of a strip of padded webbing over the shoulder From this time onwards faradism is applied to the deltoid, and the patient encouraged to lift the arm from the splint, aided at first by the masseuse When he can do this with ease and strength, it is well to remove the plaster and sling a large soft pillow between arm and chest while treatment is continued, a smaller pillow being used as the range of abduction power increases

Arthroplasty. Indications —This operation is of limited scope, as (1) with a strongly mobile scapula a fixed shoulder is compatible with good function (2) the deltoid, owing to its short leverage and range of contraction cannot act adequately if much bone is lost In suitable cases this latter defect may be remedied by replacing the lost humeral head by the head of the fibula (Elmslie), or by a mallet-shaped graft from the tibia (Platt) grafted on the stump of the humerus It will be obvious therefore that the essentials for this operation are (*a*) a deltoid at least potentially strong, (*b*) an adequate lever Granted these essentials the chief indications are (i) ankylosis in bad position (ii) a small degree of painful movement (iii) ankylosis of the shoulder with fixation of the scapula by scar or otherwise (iv) certain cases of un reduced dislocation

Technique —The incision is similar to that for excision, but is extended upwards to curve over the acromion The skin flap thus formed is dissected back and a flap of subcutaneous tissue turned down from over the deltoid The bone is exposed as for excision, and the joint then mobilized partly with an arthrodesis gouge and partly by forced movement, until the head is made to emerge from the wound The glenoid and under-surface of the acromion are freed from scar and new bone until the socket is reconstructed The head of the humerus is shaped with a gouge, sufficient bone being removed to leave a gap of ½ in when the head is replaced The raw bone is smoothed with a file and hammered with a mallet, the fatty flap turned in, and the wound closed without drainage The after-treatment is as for excision when movement is desired

Arthrodesis. *Indications* —*Flail* shoulder or *irremediable deltoid* paralysis where the muscles controlling the scapula are good and the rest of the limb gives promise of useful function, the nature of the task before the surgeon depending on the presence or otherwise of the head of the humerus *The inevitable loss of rotation at the shoulder should* be remembered as some patients may feel that this outweighs the advantages of fixation

(*a*) In infantile paralysis the head is present, and no more is needed than the removal of the opposing cartilaginous surfaces and of synovial membrane It is often well to " mushroom " the end of the humerus in order to increase the area of bony contact The anterior incision may be used, but a deltoid flap is quite permissible, the long tendon of the biceps being carefully preserved The after treatment is as for excision when movement is not desired This operation should not

be done on children under ten, as the head of the humerus is not sufficiently bony until that age is reached

(b) Where the head of the humerus is incomplete or absent, arthrodesis is more difficult Various methods have been described, but the following operation will be found to succeed in the vast majority of cases The anterior incision excises any pre-existing scar, and is extended upwards over the acromio clavicular joint and along the acromion to its base The upper end of the humerus is freed and protruded from the wound and every particle of scar tissue is removed from the space between the humerus glenoid and acromion Many small vessels will spout at this stage but they can usually be ignored until the removal of scar tissue is completed A thin slice is removed from the under surface of the acromion so as to expose bone, and the glenoid is hollowed out with a gouge to a depth of ½ in Sufficient of the end of the humerus is removed to expose medulla The neck of the acromion is then partially cut, and the end bent downwards with lion forceps On placing the end of the humerus in the prepared glenoid in the position of ankylosis, it will be seen that the acromion can be made to lie flat on the humerus. At this spot the medulla of the humerus must then be exposed with a chisel and the bony surfaces fixed together with a bone peg The wound is closed without drainage and the plaster applied

Operation for recurrent dislocation.—By this term is meant a repeated dislocation of the shoulder without trauma, often in the course of some simple movement It frequently follows an initial traumatic dislocation, with or without fracture of the glenoid rim and is also apt to be associated with epilepsy Some surgeons consider the latter a contra indication to operation but the operations to be described have frequently been performed with success on epileptics In the past even arthrodesis has been done for this condition, but the usual course has been to endeavour to increase the stability of the joint by plication of the capsule

This has often succeeded, but has been entirely superseded by one or other of the three operations to be described The majority of dislocations take place primarily downwards through the weakest part of the capsule, and in such cases Clairmont's operation is indicated Bankart, however, maintains that the initial dislocating force comes from behind, and that the capsule is torn from the glenoid ligament anteriorly, allowing the humeral head to escape A good history of the case will indicate which of these has occurred, and if need be, a dislocation can be produced at the time of operation and a decision then made

Clairmont's operation **Technique**—The patient lies on the back with a sand bag under the scapula of the affected side, and the arm by the side An anterior incision is made and the deltoid and pectoral are separated The subscapularis tendon is cleaned, and the insertion of the pectoralis major divided for a short distance from its upper edge The arm is then brought across the chest, and a

second incision made parallel with, and 1 in anterior to the posterior edge of the deltoid through the lower two thirds of its extent (Fig 37) The edge of the muscle is defined down to its insertion and a tapering strip 1 in wide at its mid part, is separated from the remainder and dissected upwards It is essential to separate the strip from its insertion with an elevator to obtain the *maximum* length As the strip is raised, its nerve and blood supply will be seen entering the under surface and must be carefully preserved The long head of the triceps

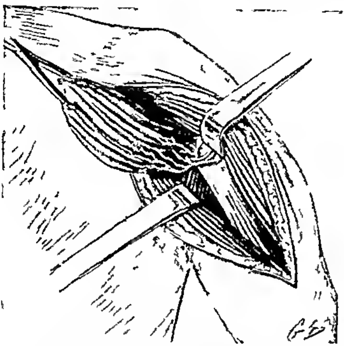

Fig 37 —Operation for recurrent dislocation of shoulder—posterior incision Deltoid flap reflected

and the tendon of the latissimus dorsi are located and with a finger in each incision the quadrilateral space is so opened up as to allow the strip to be drawn through from back to front (Fig 38) The posterior wound is then closed The apex of the strip is sewn either to the edge of the deltoid in front or preferably to the subscapularis tendon with strong catgut (No 3 chromic) The anterior muscles are re apposed and the wound closed No drainage is needed the arm being merely bandaged to the side with a pad in the axilla and the forearm supported by a sling Free movement of the elbow is allowed from the first but no movement of the shoulder is permitted for three weeks At the end of this period flexion and extension are practised daily but no abduction or external rotation is allowed until six weeks have elapsed This operation is suited to cases in which the dislocation is primarily downwards the rationale being that the detached strip acts simultaneously with the deltoid and slings the neck of the humerus upwards Some surgeons however, maintain that the strip acts merely as a pad

Bankart s operation —The anterior incision described above is carried up to the clavicle The coracoid process is exposed divided with an osteotome or bone forceps and turned down with its muscles attached The subscapularis tendon is divided The lesion is then in full view and the rent can be repaired with interrupted sutures of strong catgut or silkworm gut The glenoid lies at a great depth from the surface and fully curved needles will be needed The sub scapularis and the coracoid process are then replaced and sutured

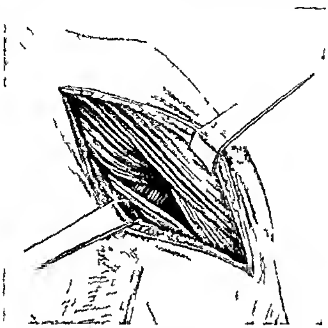

Fig 38 —Operation for recurrent dislocation of shoulder—posterior incision Flap in position

Nikola s operation —The joint is exposed by the anterior route the long tendon of the biceps cleared and the capsule opened longi tudinally with the transverse humeral ligament The tendon is divided one inch below the groove and drawn upwards out of it A drill hole is made from the lower limit of the groove upwards through the bone to emerge near the centre of the humeral head The tendon is drawn downwards through the canal and resutured to the muscle An intra articular ligament is then formed The inevitable injury to articular cartilage in the operation constitutes a serious objection to its use

Fairbank s operation —*Indication* Neglected cases of birth paralysis with fixed internal rotation of the shoulder

Technique —An anterior incision is made as for excision the joint is opened and the subscapularis tendon and coraco humeral ligament are divided Occasionally the supraspinatus may need division The wound is closed and the arm fixed in abduction and external rotation

with plaster The period of fixation will vary according to the degree of paralysis Care must be taken that the shoulder does not become fixed in abduction In most cases movement and re-education should be commenced in three weeks from the operation, although the arm must be kept on a plaster splint for a further period before voluntary control is obtained

THE ELBOW

Arthrotomy.—A simple incision for drainage, removal of loose bodies, ether lavage, etc., is best made external to the olecranon through the triceps expansion and anconeus A counter incision may be made on the inner side by passing forceps through the joint and making a careful dissection down upon the points, thus avoiding injury to the ulnar nerve

Excision. Indications —(1) Certain compound comminuted fractures, the minimum of bone being removed consistent with drainage, and the joint kept at right angles during the after-treatment The importance of the latter was abundantly illustrated during the 1914–18 War when many cases of primary excision, where much bone had been removed, ended with a surprisingly good limb if the elbow had been kept at a right angle, while disastrous flail elbows followed after treatment in extension

(2) Tuberculosis in adults where conservative methods promise to leave at best a fixed joint after prolonged treatment, where a weak mobile joint is to be preferred to a fixed one, and where there is no involvement of another large joint or amyloid disease Erasion is not recommended, as access is difficult, and the results are no better than those of conservative treatment

(3) In preference to arthroplasty in those cases where a mobile joint is desired but where there is much scarring or great destruction of the joint, or where persistent sinuses are present

Technique —A *tourniquet* is applied by some surgeons, but in the opinion of the majority it is unnecessary and harmful for this as for all other prolonged operations on the arm if necessary, it is better to use the bag of a sphygmomanometer If possible, the patient is placed in the fully prone position, the surgeon standing on the affected side, but if this position be contra indicated, the arm may be drawn across the body, the surgeon then standing on the opposite side to the one affected A vertical posterior incision is made, 4 to 5 in in length, with its centre at the tip of the olecranon This incision is made down to the bone throughout its extent, splitting the triceps Partly with a sharp rugine and partly with the knife, the tissues on the outer side are peeled away from the bones until the anterior aspect of the condyle and the head and neck of the radius are exposed, great care being taken to preserve the insertion of the triceps with its lateral expansion into the deep fascia, the anconeus, and the lateral ligament of the joint

A similar proceeding is then carried out on the inner side • The ulnar nerve is here in danger, but will probably not be seen, and can be

avoided by using the knife and keeping close to the bone The internal lateral ligament is preserved and the separation carried forward so as to expose the front of the inner condyle and the coronoid process Some surgeons insist upon the importance of the removal of the periosteum, owing to its tendency to form excessive new bone, but in my opinion this is not essential In tuberculosis or acute arthritis it will strip off easily, but in other and old-standing cases the separation is difficult At this stage the bone section may be made by protruding first the end of the humerus and then the forearm bones through the wound A better plan is to pass a large, broad elevator across the front of the humerus raising the anterior ligament from the bone, divide the humerus, and then push the forearm bones backwards and complete the section The site of section will depend on the extent of the injury or disease In most cases the humerus is divided transversely just above the condyles, and the forearm bones at the level of the neck

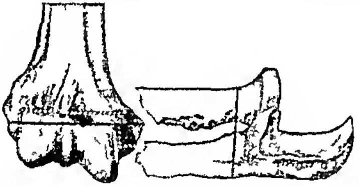

Fig 39 —Lines of section of bones of elbow joint

The continuous lines show those usually required in excision of the elbow joint The dotted lines show those employed in arthroplasty It being understood that the head of the radius has been removed at a previous operation

of the radius (Fig 39) The sawn sections should be made transversely cylindrical in order to check forward displacement of the forearm This can be accomplished either by using a Butcher's saw or by shaping the sawn sections with a gouge A gap of 1½ to 2 in *should be left when the arm is extended* If the operation be performed for tuberculosis, all diseased tissue is dissected away and isolated foci are curetted from the bones If a tourniquet has been used, it is now removed and bleeding vessels secured by ligature or under pinning, sufficient time being given for the vessels to declare themselves The wound is then irrigated with hot saline, and hæmostasis ensured The triceps is re united with interrupted catgut sutures and the wound closed, without drainage if possible

After-treatment —The joint is fixed at right angles on an interrupted metal splint and left undisturbed for ten days It is advisable to verify the position of the bones by a skiagram The stitches are then removed, and the patient encouraged to flex the joint, while the surgeon assists until an acute angle is reached Only a small range of

movement should be attempted at first as a greater range might involve some danger of re opening the operation wound This assisted active movement is continued daily henceforward the joint being advisedly fixed alternately in flexion and extension in the intervals of treatment At the end of three weeks the hand may be slung to the neck and lowered daily no other splint being required The elbow should be kept flexed at night until electrical treatment and re education have restored the power of flexion In many cases of excision although flexion and extension are well controlled there is marked lateral instability With time as the muscles strengthen this will largely disappear but where much bone has been removed a certain amount will persist unavoidably In these cases an elbow cage is required. A plaster cast of the arm is prepared care being taken to mould the plaster well over any remaining bony prominence in the condylar region On this cast a moulded leather appliance is made encasing the arm and forearm and provided with lateral steels fixed to the leather and jointed at the elbow

Flail elbow Frequently especially when little attention has been paid to the preservation of the triceps attachment and the arm has been treated in full extension either the elbow becomes completely flail or if some control remains during flexion the forearm bones must be carried up in front of the humerus before a fulcrum is obtained Such a joint even when controlled by an appliance is of little use Two courses are open Where possible the action of the triceps must be restored in order to balance the joint Simple re-attachment of the muscle to the stump of the ulna will suffice in some cases but where much of this bone has been lost the fixation of a bone-graft into the ulna in addition in order to form a new olecranon is well worthy of trial This method must necessarily fail where the bone-ends are narrow as no fulcrum can be obtained by the forearm being drawn up to the side of the pointed humerus An attempt may be made to produce ankylosis (1) by spreading the end of the humerus into a mushroom shape with a chisel leaving the chips attached freshening the ends and upper surfaces of the forearm bones and fixing the surfaces together with kangaroo tendon passed through drill holes in the bones or (2) by employing the freshened end of the humerus if it is pointed or inserting an intramedullary graft from the tibia if the humerus is broad and passing this through large holes drilled in radius and ulna the upper ends of which are previously freshened The forearm is thus fixed in the mid position and the bones are kept in apposition by kangaroo tendon passed through drill holes Prolonged fixation in a plaster including the chest will be necessary

Alternatively a mobile joint may be attempted (1) by removing scar tissue and binding the bones together with fascia lata (Platt) (2) by an arthroplasty planned to engage the pointed end of the humerus between the bevelled forearm bones (McMurray) or (3) by splitting the lower end of the humerus longitudinally and wedging the two portions apart with a small piece of bone cut off from the pointed end

In this V-shaped socket the forearm bones are engaged and fixed with kangaroo tendon, the triceps tendon being re attached as above (Aitken)

In these cases the *after-treatment* is that of arthroplasty

If these methods *fail*, the permanent wearing of a support fixing the elbow and including the shoulder is the only alternative

These results are described to emphasize the extreme importance of removing the minimum of bone when operation is performed for an acute condition, and of correct after treatment in all cases of excision

Arthroplasty. Indications —A decision whether an elbow should be left ankylosed in good position or an attempt made to give a mobile joint can only be reached after considering the occupation of the patient Manual labourers are generally better off with a fixed elbow, as at present it is impossible to promise stability of the joint especially in a lateral direction The condition of the muscles controlling the joint, the degree of scarring in the neighbourhood, and the function of the other joints of the limb and the opposite elbow must also be taken into consideration Certain cases are better treated by excision than by arthroplasty, which is much more difficult and should be reserved for cases where the bones are relatively undamaged, or there is only a small degree of painful movement

Technique —The site of incision will be governed by the position of any scars, but when possible a straight posterior incision is preferred Various methods have been used, but it will suffice to describe that advocated by Elmslie (After-treatment of Wounds and Injuries '), which has been found very successful The patient lies in the fully prone position and no tourniquet is used An 8 in posterior incision is made with its centre at the tip of the olecranon Little more than skin is reflected on either side and a flap of deep fascia and aponeurosis, 4 in long, is dissected up from over the posterior forearm muscles with its pedicle attached behind the inner condyle of the humerus The triceps tendon is defined, split into superficial and deep halves, and divided in a Z shaped manner, the deep half being divided close to the olecranon The bones are cleared as in excision The joint is either broken open, if only partially ankylosed, or divided with a curved osteotome, if fixed The humerus is made to protrude, and a portion of the end is removed the line of section being quadrilateral, leaving the two condyles and crossing just distal to the olecranon fossa (Fig 89) This latter and also the front of the bone are well cleared, and the section made transversely cylindrical (In case of difficulty, a less elaborate division, as for excision, will suffice) The articular surface of the ulna is freely cut away, only half the thickness of the olecranon and the root of the coronoid process being left The cut ends of the bones are smoothed with a file, if necessary The fascial flap is sutured over the end of the humerus the triceps re united, and the wound closed If there is ankylosis of the superior radio ulnar joint, this is better treated by excision of the head of the radius at a

previous operation The elbow is fixed at right angles and treated on the general lines of arthroplasty

Albee * realizing that stability of the joint depends largely on a balance of power between biceps and triceps and that this is impaired by the shortening of the olecranon devised an operation similar in general plan in which the olecranon is retained and detached with a tapered portion of the ulna the insertion of the triceps remaining intact After remodelling of the joint this portion is re-attached so as to lengthen the olecranon on the sliding graft principle He employs fascia lata from the thigh in preference to a local graft

Experience has shown that when as often occurs movement of the elbow is limited by a bony block attempts to remove this by operation are rarely successful and may lead to actual diminution of movement If operation be considered advisable nothing short of a full arthroplasty should be attempted in the majority of cases

Arthrodesis—It is exceedingly difficult to obtain bony union between the humerus and bones of the forearm and the simple removal of cartilage is inadequate The bones must be bound together either by kangaroo-tendon sutures passed through drill holes or preferably by a tibial bone graft driven through a hole in the olecranon up into the medulla of the humerus At least three months fixation in plaster is needed In poliomyelitis with paralysis of the flexor muscles it may suffice to excise a lozenge shaped piece of skin and subcutaneous tissue from the front of the elbow and suture the wound transversely after the method of Sir Robert Jones

Superior Radio ulnar Joint

Excision Indications—(1) Ankylosis of the joint especially when the elbow joint also is ankylosed (2) Unreduced dislocation of the head of the radius where its presence is impeding function (3) Some cases of fracture of the head or neck of the radius Early operation will be limited to the removal of loose fragments while late operation will probably involve the removal of the radial head which having become deformed will not rotate satisfactorily

Technique—A 2 in incision is made downwards from the external condyle over the head of the bone The glistening fascia over the extensor muscles will now be seen A flap of this is dissected up with its pedicle downwards The head of the radius is then cleared by dissection (not subperiosteally) and all scar tissue removed care being taken not to extend the incision too far downwards for fear of injuring the posterior interosseous nerve With a small saw or mallet and chisel the head of the bone is removed and levered out After ensuring that free movement without grating is obtained the fascial flap is tucked in round the bone stump the muscular wound closed with catgut and the skin sutured The use of a flap is not always necessary and may not be practicable

* J Bone Joint Surg Or 1933 xv 979

After-treatment —The arm and forearm are fixed in supination on an interrupted elbow-splint No movement of the joint is allowed for three weeks, but the fingers are actively exercised At the end of that time voluntary movement is encouraged No passive movement is employed at any time

The temptation to employ early movement in this as in other arthroplasties must be resisted the period of immobilization should tend to err on the long side Assisted active movements and re-education will then restore function Limitation of movement due to soft parts is well combated by the use of the plaster method which I have devised * This consists of two plaster cases meeting at the mid-forearm and enclosing the elbow and hand respectively Rotation at the point of junction is controlled by projecting metal strips incorporated in the plaster Pronation and supination can be forced by gradual tightening of tapes tied round these strips

Inferior Radio ulnar Joint

Arthroplasty of this joint has been replaced by Gallie's operation. It is a matter of common experience that fractures of the lower quarter of the ulna have a strong tendency to non union Profiting by this, Gallie advised treating ankylosis of this joint by the simple procedure of excising an inch of the lower quarter of the ulnar shaft *with the periosteum* Excellent results are obtained, the bone readily acting up to its reputation for non union, and movement taking place freely at the pseudarthrosis thus produced

The Wrist

Excision.—Systematic excision of the wrist for tuberculosis is an almost obsolete operation and need not be described The condition is rare, other tuberculous foci are frequently co existent, e g , in the lungs, the results of conservative treatment are at least as good as those of operation , and the operation itself is generally unsuccessful as far as hand function is concerned owing to the almost inevitable involvement of tendon sheaths Limited excisions may sometimes be indicated In compound fractures operation will consist in the removal of the minimum amount of bone consistent with drainage

Reconstructive operations on the wrist.—In this joint, moderate dorsiflexion is more important than mobility, as the finger flexors cannot act to advantage with a flexed wrist The indications for operation are therefore (1) ankylosis in bad position, (2) bony outgrowths limiting dorsiflexion (3) dislocations of the carpal bones

Technique —Consideration of the tendons and pre existing scars will guide the incision The most useful is a 4-in incision along the radial side of the extensor indicis with its centre at the wrist-joint Cut veins are secured the annular ligament divided, and the tendons carefully lifted from the bone with knife and elevator Lane's tissue-forceps are used to hold the tendons to either side, and the bones are then

* *Brit Med Journ.*, Aug 4 1917 ii, 750

exposed If the wrist be ankylosed, a simple cuneiform osteotomy is performed, and the wrist dorsiflexed If bony outgrowths limit dorsiflexion, they are removed Often although the removal of these outgrowths improves dorsiflexion the full position cannot be reached This is generally due to contracted tissues on the palmar side, and the joint should be fully divided and sufficient bone removed to secure either arthrodesis in good position or an arthroplasty

Displaced carpal bones or portions of carpal bones are best removed entirely If it be decided to attempt an arthroplasty, the original line of the joint is cut through with an arthrodesis gouge and the wrist forcibly flexed This will expose the bone ends With the gouge the convex end of the carpus and concave end of the radius are re formed, sufficient bone being removed to leave a gap of ½ in A piece of fascia lata is removed from the outer aspect of the thigh and wrapped round the carpal surface, care being taken to insert the edge well on the palmar side No fixation of this flap is required, and the tendons may then be carefully sutured in place by union of the annular ligament with catgut, and the wound closed The wrist is put up in dorsiflexion on a palmar metal splint reaching from the middle of the forearm to the end of the palm only The fingers are thus *left free* from the outset, and subsequent treatment will follow the lines of other arthroplasties Palmar displacements of carpal bones will necessitate a palmar incision for their removal These operations are often exceedingly difficult, and it is well not to be handicapped by too small an incision, as due regard cannot then be paid to the soft parts Both palmar and dorsal incisions may even be required to achieve the object in view with a minimum of damage

Metacarpus and Phalanges

Owing to the greater elaboration of their sheaths the flexor tendons are far less tolerant of surgical disturbance than the extensor tendons Consequently, operations on the joints of the hand should be performed from the dorsal aspect, where possible These operations will mainly consist of open reduction of dislocations, and arthroplasties When operating on a dislocation of long standing it will be impossible to decide beforehand whether the dislocation should be reduced or an arthroplasty performed Arthroplasty is indicated when either (*a*) reduction is impossible or (*b*) the cartilaginous surfaces of the joint are so damaged as to render firm fibrous ankylosis probable The mobility of the transverse metacarpal arch a matter of great importance in the maintenance of an effective grasp, depends on the integrity of the intermetacarpal and carpo metacarpal joints Where these are ankylosed a series of arthroplasties may be performed through a dorsal incision Ankylosis or unreduced dislocation of the trapezio-metacarpal joint is approached through an incision between the tendons of the extensores longus and brevis pollicis and similar conditions of the metacarpo phalangeal joint through an incision on the radial side of the long extensor The metacarpo phalangeal joints of the fingers may

be similarly treated, bone being removed, in arthroplasty, at the expense of the phalanx in order to prevent the knuckle falling back out of line with its fellows In these arthroplasties the metacarpal end should be completely cleared from the surrounding soft parts A strip of fascia lata is removed from the outer aspect of the thigh, folded in half, and sewn up into a bag with fine catgut This bag is then slipped over the bone end and easily remains in place

After these operations, extension should be applied to the digit for two weeks before movement is allowed It is best effected by applying a plaster cast to the wrist and palm, previously encased in wool or felt, and incorporating in the plaster a stiff wire loop stretching beyond the extended fingers and bent into a notch opposite the affected finger A tape is attached to the finger with adhesive plaster, and tied over the notch

Sacro iliac Joint

Tuberculosis of this joint is a disease chiefly of adolescent and adult life, and if it does not readily yield to conservative means may be treated

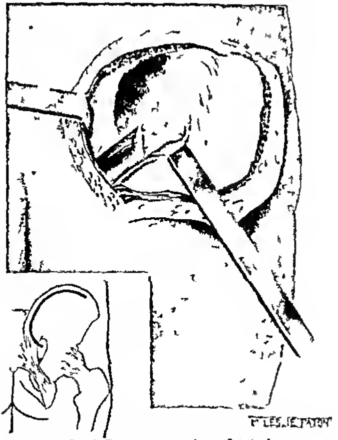

Fig 40 —Smith Petersen s operation Inset, skin incision.

on the same radical lines as in other joints A semilunar skinflap is turned forwards from over the joint, the glutei separated from the

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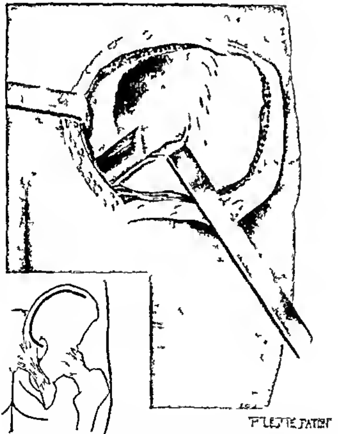

Fig 40 —Smith Petersen s operation Inset skin incision

on the same radical lines as in other joints A semilunar skinflap is turned forwards from over the joint, the glutei separated from the

bone and an opening made into the joint with hammer and chisel all diseased bone being removed and abscesses evacuated

More recently arthrodesis has been successfully performed both by intra and extra articular methods Of the former that of Smith Petersen is the best An incision is made along the posterior two-thirds of the iliac crest curving round the posterior superior iliac spine and running forward parallel to the gluteus maximus for 2 or 3 in If the sacro-iliac joint be projected on to the outer aspect of the cleared ilium the inferior edge will correspond with the sacro-sciatic notch and the anterior with the middle gluteal line (Fig 40)

With a motor saw and osteotomes a rectangular block of bone is cut out from the ilium opening the joint the cartilage and diseased material is curetted away and a socket of corresponding size cut in the sacral surface After removal of cartilage the block is countersunk into this socket crossing the joint Additional fixation may be obtained by osteotomy of the edges of the slot

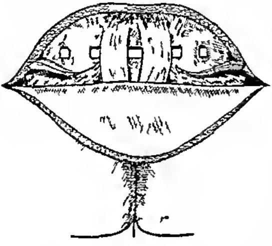

Fig 41 —Author s operation for sacro iliac fixation (trans sacral graft)

Of extra articular methods that devised by me* has proved of value and has the advantage of extreme ease A semi lunar skin flap turned down exposes both posterior superior iliac spines and the muscles between them Both spines are cleared and the intervening spinous process removed from the sacrum leaving a raw area Tunnels of $\frac{3}{8}$ to $\frac{1}{2}$ in diameter are made in the two spines and a tibial bone graft of suitable size driven across passing through both tunnels under the muscles and with its raw surface in contact with the raw area on the sacrum (Fig 41) No extra fixation is required and the two sacro iliac joints are held together as by a tie beam

Considering the extreme gravity of sacro-iliac tuberculosis one or other of these methods is indicated They are often suitably employed in such milder conditions as painful arthritis or intractable instability of the joint Postoperative fixation first by plaster and later by a pelvic brace will be indicated the duration naturally varying according to the severity of the disease

The Hip

To avoid repetition operations on this joint will be classified according to the method of approach

* Journ Bone and Joint Surg Jul 19 5 vol 491

Anterior approach. Indications.—(1) Drainage of acute arthritis and epiphysitis

(2) Removal of foreign or loose bodies

(3) Capsulotomy, or division of the anterior part of the capsule, in obstinately flexed hips This operation is most often needed in amputation stumps where it has been found impossible to correct the abduction and flexion deformity by other means More rarely, it may be necessary in old-standing cases of poliomyelitis with extreme flexion deformity, although in these cases section or displacement downwards of the muscles will usually suffice

(4) Arthrodesis by Albee's method.—In this operation, which has for its object the fixation of painful osteo-arthritic hips, the joint is quickly exposed by the anterior incision with the minimum of disturbance, and portions of bone are excised from the upper surface of the femoral head and adjacent acetabular roof so as to oppose two flat, raw, bony surfaces with good expectation of firm bony union and consequent cessation of pain

Technique.—The patient lies on the back and the surgeon stands on the affected side A 4 in incision is made downwards and slightly inwards, commencing ½ in below the anterior superior spine The interval between the tensor fasciæ femoris and the glutei on the outer, and the sartorius and rectus on the *inner side* is opened up, a branch of the external circumflex artery being divided at this stage The capsule is exposed and freely opened and the joint explored with the finger, the hip being flexed In infective arthritis and epiphysitis the head of the bone will probably need removal If dead and loose, it can be levered out with an elevator, but otherwise, if its removal be indicated, the neck must be divided *in situ* with a keyhole saw Very great care must be taken of the surrounding soft tissues, and it is advisable to use a saw with a rounded extremity

In infective cases it may be necessary to have a counter-incision in the buttock and some form of continuous irrigation, the limb being placed on a Thomas's splint or abduction frame, with extension in the position of ankylosis

Antero-external approach. Indications.—Where exposure of the top of the joint is required, as in open operation for the reduction of congenital dislocation

Technique.—An incision similar to the above is extended upwards for 3 in along the crest of the ilium With a periosteal elevator, the tensor fasciæ femoris and glutei are stripped from the ilium downwards and backwards until the joint is reached, and the origin of the rectus femoris from the anterior inferior spine detached After the required intra-articular operation is concluded the muscles are replaced and sutured in position with catgut In this as in all operations involving extensive periosteal separation, the amount of hæmorrhage varies within wide limits Drainage will only be required where

persistent oozing is taking place from small points not controllable by ligature This approach is most useful in children

Lateral approach —This method has gained favour in recent years owing to the very slight disturbance of the soft parts involved and the practical absence of hæmorrhage It is applicable to Whitman's

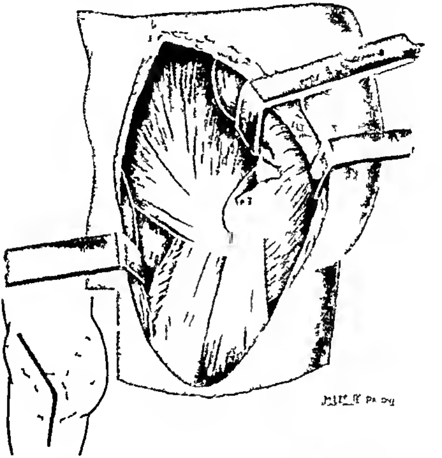

Fig 42 —Anatomy of lateral approach to hip joint Inset, skin incision.

reconstruction operation and extra articular arthrodesis It may follow one of two types —

(1) An incision passes from just *behind* the *anterior superior* spine to the great trochanter and thence downwards for about 3 in along the line of the femur (Fig 42) The interval between the tensor fasciæ femoris and glutei is opened up and the latter turned upwards and backwards with the great trochanter separated with an osteotome

(2) If greater room in a *posterior direction be required* the *incision* should take the "goblet" form (Murphy) the stem corresponding to the femur and the cup to the glutei the two meeting at the great trochanter

Posterior approach.—This is a much more severe operation than the others and should be reserved for cases requiring a very extensive exposure of the joint and possibly dislocation with the inevitable shock caused thereby. However it is a valuable method and in the rare cases where drainage is required the position of the wound will naturally be favourable. The patient lies on the sound side and the surgeon faces the back. An incision is made from the posterior edge of the tip of the great trochanter downwards along the femur for 3 in. and upwards for 4 in. towards the posterior superior iliac spine (*Fig. 43*). If arthroplasty be intended the skin is well dissected back on each side and a large fat and fascia flap raised from the subjacent gluteus maximus.

Fig. 43.—Anatomy of posterior approach to hip-joint. Inset, skin incision.

The gluteus maximus is then split in the line of its fibres and its attachment to the femur peeled off for a short distance and partially divided. Many vessels are cut at this stage and should be tied off before the operation is continued. Two courses are now open. If but a limited exposure of the joint be required the interval is found between the glutei medius and minimus on the one side and the pyriformis on the other and the former two muscles are stripped from the great trochanter forwards until the anterior intertrochanteric line is reached. The other muscles inserted into the trochanter are divided. The digital fossa is the site of an arterial anastomosis and considerable bleeding may be encountered here. It is advisable to ligature vessels during the progress of the operation as an accumulation of forceps hampers the view. To separate the muscles from the bone effectively it is necessary to rotate the limb inwards and outwards as occasion requires. With a fixed hip this cannot be done and the operation becomes unnecessarily difficult. Where there is any difficulty of this kind it is easier and gives a better exposure to divide the great trochanter. An aneurysm needle

is passed round its base in order to define the extent and the base divided with a broad osteotome The bony process can then be retracted upwards with the muscles attached

The capsule is incised (in arthroplasty excised) and the gluteal origins are stripped away from around the acetabulum with an elevator By these means the superior posterior and most of the anterior surfaces of the head and neck of the femur are exposed One of three proceedings may now be adopted—excision arthroplasty or arthrodesis

1 Excision Indications —(1) Extensive destruction of the joint by injury (2) Some cases of pathological dislocation Where stability of the limb is already ensured by the fixation of the displaced head by fibrous tissue etc malalignment of the limb will be better corrected by osteotomy (3) Rarely tuberculosis

Technique —The neck of the femur is either divided *in situ* with a keyhole saw or an osteotome the surrounding parts being protected with Lane s elevators or is sawn through after the joint has been dislocated by rotation of the limb The site of section will depend on the limits of the disease no more bone being cut away than is consistent with the removal of disease and provision for drainage

2 *Arthroplasty* *Indications* —(1) Cured disease tuberculous or other infective arthritis with markedly limited movement (2) Double ankylosis of the hips (3) Limited painful movement in toxic arthritis especially when atrophic if not otherwise contra indicated

Technique —With a broad arthrodesis gouge the original joint is re-formed In cutting out the head if there be complete bony union between femur and pelvis advantage may be taken of this to cut the bone so as to leave a shelf projecting from the upper edge of the acetabulum to minimize the chances of subsequent dislocation It is not necessary to cut through the whole extent of the union for when the upper posterior and under parts have been cut forcible movement of the limb will fracture the remainder and dislocate the head With the gouge the acetabulum is well hollowed and the head remodelled enough bone being removed to leave a gap of 1 in Some surgeons employ a brace and special bits for this purpose but this is unnecessary The raw bony surfaces are hammered to decrease callus formation and the fatty flap originally preserved is interposed Murphy employing his goblet incision (p 136) left this flap attached above and succeeded in both lining the acetabulum and covering the head with it thus interposing two thicknesses of fascia This is certainly difficult and also unnecessary a single layer will suffice and no hesitation need be felt in dividing the pedicle if the flap does not lie easily in place without tension The flap may be stitched round the acetabulum with catgut or more easily applied round the femoral head and retained in place with a purse string suture of catgut If no flap for interposition is available a detached piece of fascia lata may be employed (For after treatment *see* p 111)

Very good results were reported by Murphy but in my opinion at

least equally good results are obtained by Whitman's operation which is applicable to cases of arthritis and non union of intracapsular fracture provided they be carefully selected from the point of view of the co operation of the patient in the after treatment

Whitman's operation —By an antero lateral or posterior approach the trochanter and femoral neck are exposed The former is divided at its base and displaced upwards with the muscles attached In cases of arthritis the hip is now dislocated warning having been previously given to the anæsthetist, in order that the inevitable shock may be countered The head of the femur is removed and the stump of the neck rounded off and placed in the acetabulum With the thigh in abduction the trochanter is re attached by a peg, wire or nail to a rawed area lower down on the femur The leverage power of the glutei is thus preserved The after treatment is that of arthroplasty.

Although it is not strictly an operation on the joints, reference may be made to the operation of bifurcation (Lorenz) in the treatment of painful arthritic hips * Here a transverse inter trochanteric osteotomy is performed, and the lower portion is pushed inwards towards the acetabulum Union occurs, and weight bearing is in part transferred to the pelvis with relief of pain

3 **Arthrodesis.** Indications —(1) Painful unilateral hypertrophic osteo arthritis It is exceedingly difficult to lay down hard and fast rules for the treatment of this disease Relief of pain is the primary consideration In a large number of cases the wearing of a caliper splint for a varying period will give relief In young people especially if the disease is not progressive arthroplasty may be attempted, but where palliative treatment is of no avail either fixation or the operation of Sir Robert Jones (p 143) or the intertrochanteric osteotomy of McMurray is the only means by which relief can be ensured

Arthrodesis for this condition may be performed either by Albee s method of anterior incision or by the posterior method The latter is however, a severe operation in the aged and feeble

When there is a very small degree of painful movement in both hips, it is advisable to perform arthrodesis on one side to provide a stable hip and an arthroplasty or Whitman operation on the other

(2) Paralysis of all muscles controlling the hip joint if the knee be under control

Technique —All cartilage is removed from the joint surfaces These are then carefully fitted together Some surgeons employ a bone-peg or nail to fix the bone surfaces together, but this in most cases is unnecessary

After either of these operations the trochanter if it has been separated, is pegged in place, either in its original position or lower down the shaft The muscles are re united with catgut it is advisable to do this carefully in two or more layers to avoid hæmatoma In infective cases drainage is obtained by a tube reaching down to the joint, but

* M Murray *Brit J Bone Surg* 1934-35 N 88 xxii p 716.

After-treatment of hip-joint operations.—In all cases the limb should be put up in the position of ankylosis In arthrodesis this is best effected by the immediate application of a plaster spica reaching from thorax to toes as obviously no extension is required (Figs 15, 46) The progress of ankylosis can be gauged by skiagrams, but usually at least three months will be necessary to secure a sound union The application of plaster will enable the patient to leave bed and move about on crutches at the end of a fortnight if necessary, an obvious advantage in dealing with a patient of advanced years

Where possible, hip joint operations should be performed on a Hawley

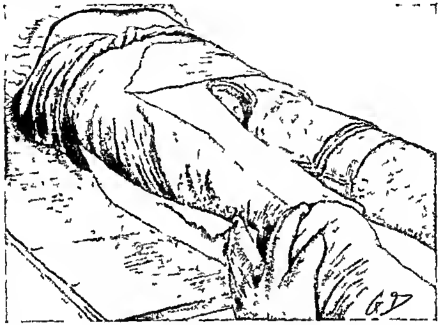

Fig 45 —**Plaster spica to hip**

First stage showing wool covering and plaster-strengthening strips in position The latter should not be applied until the whole has been covered by a layer of plaster bandage

table (Fig 34, p 120) This table allows extension to the limb during the operation, if necessary and greatly facilitates the application of plaster If this table be not available, a pelvic rest is placed beneath the sacrum and the limb supported by an assistant

The initial *postoperative plaster* should always be carried down to the toes, as otherwise considerable trouble may ensue from swelling of the distal parts Later, the ankle and knee may be freed by cutting away the plaster Upwards, the plaster should reach just above the lower edge of the thorax, and on the opposite side the anterior superior iliac spine must be included In order to ensure fixation, it is a good plan to include the upper 6 in of the opposite thigh during the first three weeks after the operation In applying the plaster cast, pieces of felt are bandaged over the lower ribs, the whole surface is well padded with wool and covered in with a few plaster bandages Experience

teaches that the parts of a spica most likely to break are at the inner and outer ends of the fold of the groin, two thick plaster strips are therefore applied, vertically along the outer side of the hip and from the inner side of the thigh upwards over the pubes to the opposite iliac spine More bandages are then applied until the cast is sufficiently thick The plaster must be well moulded over the anterior superior spines and round the knee

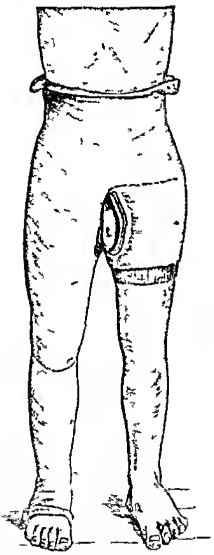

Fig 46—Plaster spica to hip (complete)
The dotted line indicates line of removal of a portion of the plaster at a later stage (*vide text*)

In other cases, where no drainage has been employed and dressings do not need changing frequently, the limb is put on a Thomas's bed-splint with a large ring, and moderate extension applied The splint is suspended from a Balkan frame placed diagonally to the bed, so as to keep the limb in abduction In cases of arthroplasty and Whitman's operation it is useful to apply an extension to the leg, and a plaster spica, from ribs to ankle, over this From 5–10 lb extension is then applied After 10 days the plaster is bivalved and movements are encouraged and after 8 to 12 weeks the patient is allowed to put some weight on the leg, with or without the support of a caliper splint according to the stability of the joint Crutches will be used until full confidence is regained

After Whitman's operation fixation in plaster is maintained only until it is thought that firm bony union of the re attached trochanter has taken place After this daily assisted active movements of the joint are instituted a useful method, at this stage being to sling the limb from a Balkan frame and allow the patient to control movement by a pulley

Where repeated access to the wound is required as in infective cases a Thomas s abduction frame is indicated By some surgeons

this apparatus is employed as a routine for all cases, but for those unfamiliar with its use it is a difficult appliance on which to make a patient comfortable although the perineal band around the opposite groin is very useful in preventing accommodative tilting of the pelvis

Jones's operation—Mention must be made of Sir Robert Jones's operation for painful osteo arthritic hips in old and fragile patients A vertical external incision is made, 4 in in length, in the plane of the great trochanter A thin slice of this process is chiselled off and turned upwards with its attached glutei The neck of the femur is then cut through with an osteotome, extension applied to the limb so as to separate the surfaces and the cut trochanter turned in and pegged to the proximal end of the femoral neck A caliper must be worn for a prolonged period if not permanently

The advantages of this procedure are that it cures pain and retains mobility, while avoiding the shock of disarticulation, a much overrated risk in healthy individuals but a matter of concern in those of advanced years

THE KNEE

Arthrotomy.—Indications (1) Septic arthritis For drainage of the joint, lateral incisions on either side of the patella and the insertion of drainage-tubes will often suffice but it may be necessary to make a counter incision in the popliteal space by cutting down on a pair of forceps passed through from the front In very severe purulent arthritis the ligamentum patellæ should be cut through, the patella turned upwards, and the knee fixed in a flexed position Continuous irrigation can then be employed When the sepsis abates, the knee can be straightened and the ligament sutured Naturally, this is a severe proceeding but it may occasionally save a limb, the prognosis is eventual ankylosis

(2) Etherization of the joint

(3) Penetrating wounds of the joint and the removal of foreign bodies

(4) Removal of loose bodies If the offending body be situated in the anterior part of the joint it is located by palpation if possible, and incision made over it Often the patient is able to bring the loose body to the surface of the joint at will In these cases local anæsthesia renders the operation very simple as the patient can move the knee and work the loose body into the wound Where many loose bodies are present, incisions may be required on both sides of the joint

Loose or foreign bodies (such as broken wire from a patellar suture) may lie in the posterior part of the joint and show no tendency to come forward Some surgeons obtain access to this part of the joint through a median posterior dissection, displacing the popliteal contents to the outer side It is far preferable however, to approach through a lateral incision The knee is flexed to a right angle, thus displacing the popliteal structures backwards out of danger Incision is made longitudinally, either on the inner or outer side or both according

to the position of the body On the outer side the joint is reached in front of the biceps tendon and on the inner side between the semi tendinosus and semimembranosus The joint is freely opened a broad retractor is inserted and the popliteal structures are forcibly retracted backwards Very good access to the back of the joint is thus obtained When the joint is abnormal it may be possible to attain both sides through one incision preferably the outer but if normal the view is obstructed by a synovial reflection Other methods of approach are described below

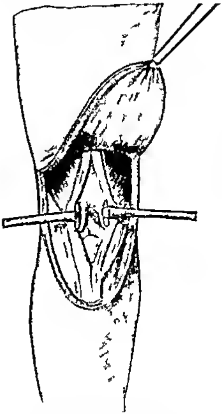

Fig 47 —Split patella method of arthrotomy of knee as seen with joint flexed

Arthrotomy for intra articular lesions —The preliminary application of a tourniquet is necessary for all these operations Where an extensive exposure of the joint is required one of two methods is available

(1) The split patella method of Robert Jones —This gives a very good view of both sides of the joint but is open to the objection that the trauma is large and consequently there is a risk of subsequent arthritis

A U shaped skin flap is turned up (*see* p 149) for excision the reflection being carried up to the level of the top of the suprapatellar pouch A lateral semilunar flap is usually as convenient A vertical median incision is then made from this point downwards dividing the quadriceps tendon patellar capsule and ligamentum patellæ With a saw the patella is divided in this line until the cartilage is reached the final division being made with the chisel or a strong knife The synovial membrane is divided in the same line throughout the extent of the incision With the knee flexed and the two halves of the patella retracted a very complete view of the joint is obtained (Fig 47) At the completion of the operation the two halves of the patella and the tendons are united with catgut The wound is closed and dressed and the tourniquet removed It is necessary to apply a posterior splint for three weeks

(2) Internal lateral incision (Fig 48)—Here the incision is a curved one along the inner side of the patella and suprapatellar pouch The skin and fascial incisions are so made as not to be coincident In Timbrell Fisher s variety of this approach after reflection of the

skin the fascia is divided in the middle line dissected and strongly retracted inwards The capsule and synovial membrane are divided ¼ in internal to the patella and care is taken to make the upper part of the incision oblique so as to avoid division of the fibres of the vastus internus The patella is displaced outwards as above A similar operation can be performed on the outer side

Indications —(1) Radical removal of hypertrophied villi worn or torn cartilages obstructing osteophytes and diseased synovial membrane in cases of osteo arthritis This operation is less often performed than it deserves but must be reserved for carefully selected cases It is in the nature of an erasion A very guarded prognosis of subsequent function must be given Some cases recover a surprising degree of movement others are disappointing but there is always a satisfactory diminution of pain

(2) Certain cases where the nature of the intra articular lesion is so doubtful that a complete view of the joint is essential Some surgeons employ the method as a routine for the removal of torn cartilages but this is quite unjustifiable as the trauma is unnecessarily severe

(3) Reconstruction of ruptured crucial ligaments This operation is on its trial and should not be performed unless it is impossible to control the disability by a knee cage Very good results have however been obtained and the operation is not exceptionally difficult its success or otherwise depending mostly as in many other orthopædic operations on the after treatment The anterior crucial ligament is replaced by a *strip of fascia lata* from the thigh passed through holes bored in femur and tibia in such a way that the lost ligament is exactly reproduced and pulled tight all fixation being extra articular The knee is fixed at 160° the extra 20° of extension serving to render the new ligament tighter when it has become firmly fixed Loss of the posterior ligament is rare and its reconstruction is still more rarely required Attempts have been made to use the semi tendinosus tendon

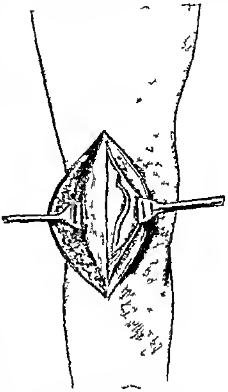

Fig 48 —Internal lateral incision for arthrotomy of knee

After treatment —The knee is kept immobile for six weeks and a knee cage is worn until re education and electricity have restored the power of the vasti muscles and the stability of the knee

Removal of internal and external semilunar cartilages Indications —It must not be assumed that removal is indicated in every case in which a characteristic history is obtainable A large percentage of cartilages are detached at their anterior end only and often become re-attached although some disability may persist owing to adhesions Where therefore there is a history of one or two lockings in the past and only weakness and possible recurrent synovitis recently it is correct to mobilize the knee under gas adhesions being ruptured on full flexion and rotation If adhesions alone be present this followed by a six weeks course of electrical and exercise treatment to the

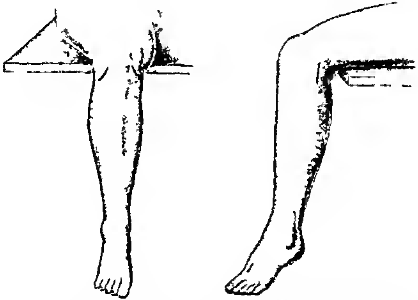

Fig 49 —A Line of incis ons for removal of internal and external semilunar cartilages B Approach to posterior part of jo nt on outside nternal approach is s milar

quadriceps will cure the patient When however there is a history of recent recurrent locking it is certain that there is a definite tear and removal is indicated Some surgeons advise that the quadriceps be strengthened before operation but *it is certain that* a *definitely* displaced cartilage produces a vicious circle and it should be removed as the first stage of treatment The external cartilage is more rarely injured but in addition to cases of injury its removal is indicated for certain cases of clicking knee and for cysts of the cartilage

Technique —Rigid asepsis is absolutely essential but repeated and forcible scrubbings of the skin are to be avoided as tending to liberate more bacteria than they destroy The ordinary bath and iodine pre paration will suffice the knee being again painted at the time of the operation A tourniquet is applied to the thigh and the end of the table lowered to allow both knees to flex The area of operation is surrounded with towels one enveloping the foot and leg of the affected

side. The surgeon sits on a low stool or sterilizing drum. While there is no advantage in handicapping oneself by a too small incision, there is no advantage in making a larger one than is necessary. A 1½-in. incision is made downwards and slightly backwards from midway between the patella and femoral condyle to the upper edge of the tibia ; this will not endanger the internal lateral ligament. (Fig. 49.) The incision exposes the capsule. Small wound-towels are clipped to the edges of the incision by tissue-forceps or Michel's clips. With a fresh knife the capsule *and synovial membrane* are opened in the same line. Failure to open the synovial membrane is a common error, there being an extensive fatty area between it and the capsule. The edges of the opening in the joint are held apart by tissue-forceps or small retractors, and a blunt hook is passed into the joint, and round the anterior end of the cartilage if it is loose.

With a thin-bladed knife the anterior attachment is divided and a pair of Ochsner forceps applied to the cartilage. If the anterior end is firm, it does not follow that the posterior part is uninjured, and the operation should proceed. Traction is made on the cartilage, forwards and towards the middle line, and its circumferential attachment divided with the knife. By a combination of cutting and traction the cartilage is removed, no tags being left behind. The synovial membrane is then sewn with a continuous catgut stitch inserted with a Reverdin's needle or a curved needle on a holder, the same stitch uniting the capsule on the return journey, and being tied to the end of the original knot, left long for this purpose. The knots are tied with forceps. (Fig. 50.) The skin is joined with salmon-gut. The foot of the table is raised, the wound dressed with plenty of wool, and the bandage applied very

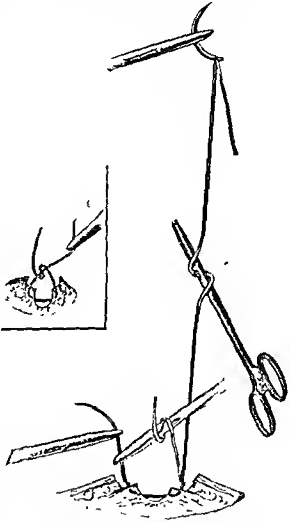

Fig. 50.—Method of tying knot in suture with forceps as applied to closure of wound in knee-joint.

smoothly and carefully No splint is needed The tourniquet is then removed

A precisely similar operation is required for removal of the external cartilage Where both may be injured the internal should be explored first, as it is possible to obtain a view of the external cartilage from the internal incision but not vice versa If the external cartilage be found to be injured, a separate incision will be needed for its removal

After treatment —On no account must the bandage be loosened for at least forty eight hours There should be very little pain if the bandage has been applied *smoothly*, and loosening will invite hæmarthrosis Should hæmarthrosis occur there will be a febrile reaction, which need not cause alarm or suspicion of sepsis If the effusion persists, it should be aspirated and the knee re bandaged firmly, convalescence being necessarily delayed The stitches are removed on the tenth day, and the patient allowed to get up A back splint is not necessary, but it is well to apply one for the first two days after the patient gets up as it gives confidence Electrical and exercise treatment is then employed for six weeks, if time permits The object of this is to increase the efficiency of the quadriceps and the vastus internus, especially the latter Daily faradism to this muscle will increase its strength until it can again serve to prevent lateral instability of the joint, while gymnastic exercises will strengthen the whole extensor apparatus and ensure full and unimpeded range of movement Some surgeons advise a much longer period of recumbency This is not only unnecessary but actually harmful, as the trauma of the operation is not great, and an early return to function is obviously advisable if muscular wasting is to be avoided

Erasion for tuberculosis is rarely indicated, such cases as could be treated by this measure being curable by conservative methods It is obvious that if radical operation be performed, every stage between erasion and a full excision will be met The advocates of erasion mention as suitable for this operation exactly those cases which are curable by other means and insist on a subsequent period of fixation which would usually be adequate to effect cure without operation

Arthrodesis.—The difference between this operation and that of excision (*see* below) is merely one of degree, as in no case should any unnecessary bone be sacrificed.

Excision Indications —(1) Tuberculosis Extensive removal of bone in children is strongly contra indicated as interfering with the growth of the limb It still remains a justifiable operation in adult cases which do not yield readily to conservative means and yet are not sufficiently severe to justify amputation. With modern artificial limbs, there should be no hesitation in amputation where there are excessive destruction and sinus formation

(2) Disorganization of the joint by old infective arthritis or osteoarthritis, especially if there is much pain

(3) Certain compound comminuted injuries (e g gunshot) Modern treatment has much reduced the necessity for this operation, and in any case the removal of bone will be strictly limited to the removal of loose fragments and the provision of drainage In doubtful cases, primary amputation is advisable

(4) Flail joints due to paralysis the object being to lessen the amount of apparatus necessary This is especially applicable to hospital cases

(5) Unsound ankylosis with tendency to flexion deformity and triple displacement

No excision or arthrodesis should be performed on a knee which is flexed more than a few degrees as too much bone must then be removed In active disease the knee must first be straightened by extension, and in cases of ankylosis simple osteotomy along the joint line, followed by extension, is indicated It is dangerous to correct fully at one sitting a knee that has been flexed for a considerable period and no advantage is gained, as gradual extension will suffice

If it be impossible to keep the patient in bed during correction a succession of plaster casts applied at intervals of ten days will achieve the desired result

Technique—A tourniquet is applied to the thigh and the knee flexed over the end of the table, if possible A great number of different incisions have been employed and access to the joint has been obtained above, below, and through the middle of the patella The one now most generally accepted is U shaped, commencing above one femoral condyle, descending vertically crossing the front of the tibia at the tubercle, and ascending to the opposite condyle This flap is dissected upwards, the skin only being raised as far as the upper border of the patella The ligamentum patellæ and lateral parts of the capsule are divided in the same line as the original incision, and the whole flap raised, including the patella In tuberculous cases the suprapatellar pouch is dissected away, the intra articular structures are removed, and all side tracks of disease opened up and cleaned A few touches of the knife will then free the lower end of the femur on its lateral and posterior surfaces By pushing the tibia backwards the femur is made to project and the bone section begun In tuberculosis one-third to two thirds of the condyles should be removed, in arthrodesis in children the cartilage only is cut away in adults one third of the condyle is removed the resultant shortening being an advantage, owing to the easier clearance of the foot from the ground in walking with a stiff knee The femur is divided with a Butcher's saw at right angles to the axis of the shaft The tibia is then brought forward, and a thin slice removed from its upper surface, just sufficient to expose cancellous tissue Free access to the back of the joint is now obtained and diseased tissue can be removed by dissection The bones are fitted together, the alignment of the limb tested, and any errors corrected by removal of bone After all diseased tissue has been excised, the patella may be either removed or left If possible, Tubby's plan of removing the cartilage from the patella and baring the corresponding

areas of the anterior surfaces of femur and tibia, and pegging the three together, should be adopted, this method is certainly of value in ensuring sound union Some surgeons employ two excision pins driven in through separate small incisions through the tibial tuberosities into the opposite femoral condyles in X-fashion, to ensure approximation If the bones fit well, this is usually unnecessary Should there be reason to anticipate difficulty in obtaining bony union between the cut surfaces, or should this have failed, the insertion of a graft crossing the joint ensures ankylosis This graft should be cut from the front of the tibia on the affected side immediately below the line of section of the bones and fitted into a groove in the femur It will be found to fit better if its direction be reversed The deep tissues are closed with catgut and the skin sutured A generous dressing is applied, and bandaged very smoothly and carefully, and the tourniquet removed The limb is enclosed in plaster from foot to pelvis a portion being cut round (but not removed) over the site of the incision, as the plaster is setting This "lid" is kept in place by a bandage and can be lifted to inspect the wound

After-treatment—The wound is disturbed as little as possible, morphia being given to allay pain. On the tenth day the "lid" is

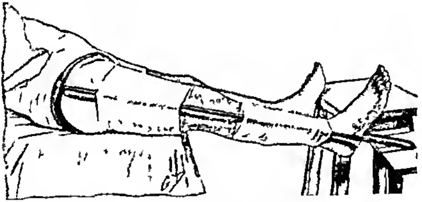

Fig 51—Method of employing a Thomas's splint and plaster for fixation after excision of knee.

Immobilization is obtained without preventing free access to the affected area.

removed, the dressings are cut through, the stitches removed the wound redressed and the "lid" replaced After three weeks a new plaster is applied under an anæsthetic, but this need not include the pelvis A closer fit will be obtainable as less dressing is needed The patient can then get up on crutches, but no weight must be borne on the limb In tuberculosis cases where more frequent attention may be needed, the limb may be put on a metal splint with an interruption at the knee An excellent method also is to encase thigh and leg in plaster, apply a Thomas's splint to the limb, and fix the splint to the leg with additional bandages, enclosing the splint (Fig 51) This method effectively prevents separation of the bony surfaces

In non tuberculous cases after two months a cast is taken and a moulded leather or celluloid case is made to fit, lateral steels being prolonged downwards into sockets in the boot The patient can now bear weight on the limb The date at which weight can be taken in tuberculous cases will depend on the symptoms and the evidence of skiagrams

A Thomas's knee-splint, changed later to a caliper if the disease remains quiescent, should in any case be worn for at least a year

Arthroplasty of the knee.—In the knee more than anywhere else the selection of suitable cases is essential Firm bony ankylosis in good position should not be lightly disturbed As in synovectomy, patients should understand that considerable discomfort is to be expected during after-treatment and they must be prepared to face this Fear of lateral instability is the chief bugbear

The joint is exposed as for excision Originally some effort was made to imitate the normal contour of the knee, the ankylosis was cut through and the opposing surfaces made transversely cylindrical, the femoral convex and the tibial concave Recently Albee has practised a method in which the surfaces are V-shaped at an angle of 120°, and no attempt is made to imitate a normal joint Lateral instability is much lessened thereby, and more bone can be safely removed In either case the new joint is lined by fascia taken from the thigh Fixation in plaster with extension is maintained for at least 6 weeks

In cases where ankylosis is limited to the femoro patellar joint the rest of the joint being healthy, arthroplasty is most useful Incisions are made on either side of the patella the ankylosis is cut through, and the deep half of the patella removed The femoral surface is smoothed and a strip of fascia lata turned down from the outer surface of the thigh, passed through between the two patellar incisions, and fixed by catgut sutures at the four corners The joint is immobilized for four weeks The condition calling for this operation is somewhat rare, but the results are excellent, almost complete range of mobility being obtainable by careful and prolonged exercises

Operations for the repair of fractures of the patella are described in the article on Bones (p 257)

It remains to indicate briefly the procedures that have been adopted for the relief of **recurrent dislocation** of this bone —

(1) Correction of associated genu valgum by osteotomy, the dislocation being commonly outward

(2) Excision and resuture of a portion of the capsule on the inner side, with division of the capsule on the outer side, the synovial membrane not being opened

(3) Arthrotomy on the outer side of the patella, and the raising of the ridge on the outer femoral condyle with a hammer and chisel in order to increase the normal barrier to dislocation

(4) Transplantation of the tubercle of the tibia and attached ligamentum patellæ to the inner side, especially if the vastus externus be

well separated externally and the tibial tubercle be displaced to the inner side without complete separation from its periosteal attachment to the tibia (Elmslie and Malkin)

(5) Fixation of the patella to the inner side by a free fascial graft to reinforce the capsule

(6) Transplantation of the semitendinosus into the patella

(7) Transplantation of the outer half of the patellar tendon behind the inner half into the tibia

The condition is a difficult one to cure Probably methods (1) (2) and (4) either alone or in combination offer the most promising outlook

The Ankle

Arthrotomy for drainage is best performed by incisions in front of the two malleoli a drainage tube being drawn across between the two incisions behind the extensor tendons Where drainage of the posterior part of the joint is required an incision is made behind the peroneal tendons and a counter incision made on the inner side by cutting down on forceps passed through the joint In compound fracture involving the ankle the site of incision will be determined by the injury sufficient bone being removed to ensure drainage and the foot immobilized in the position of ankylosis

Excision of the ankle for tuberculosis is rarely required as (1) conservative treatment usually suffices and (2) the tarsus is usually extensively involved and the astragalus at least must be sacrificed

When operation is indicated amputation through the mid tibia will remove the disease more surely and provide a better walking mechanism The classical excision need therefore not be described

Arthroplasty and arthrodesis—These two operations must be considered together as it is frequently impossible to foretell before the operation which of the two will be found feasible

Indications—(1) Ankylosis in faulty position (2) Limitation of dorsiflexion by a bony block (3) Limited and painful movement

Technique—A tourniquet is applied and a 4 in longitudinal incision made along the front of the joint avoiding the tendons these are held to one side and the extensive fatty mass beneath them is dissected downwards in a flap The front of the joint is thus exposed A simple bony block can then be chiselled away If the joint is more extensively injured or ankylosed a wedge is removed from the site of the original joint with an arthrodesis gouge If the bone is hard arthroplasty may be attempted if soft and spongy arthrodesis must be performed In the former case a gap of ¼ in is left throughout the joint and the flap of fat turned inwards to line the new joint The wound is then closed and dressed and the foot placed in the position of ankylosis on a club-foot shoe

The tourniquet is now removed On the tenth day the stitches are taken out and if arthroplasty has been attempted the patient is asked

to move his ankle If he can do so, movement will probably result, if not, ankylosis In either case, fixation in plaster for at least four months is required, but the patient should be allowed to walk on the plaster at the end of four weeks, this being essential to restoration of function

If artbroplasty be impossible, the bones are shaped to fit, and no flap is interposed

If much bone has been removed good co aptation may be impossible and better bony contact is obtained by performing an oblique osteotomy of the fibula, severing the malleolus and allowing it to be pushed inwards into contact with the astragalus A sliding bone graft from the front of the tibia inserted into the neck of the astragalus is a useful additional measure

Tarsus and Metatarsus

For operations in this region the reader is referred to the article on General Orthopædics (p 87 *et seq*)

CHAPTER V

OPERATIONS ON TENDONS

By the late R. C. ELMSLIE, O.B.E.

SURGICAL ANATOMY

The tendons consist of longitudinally arranged bundles of fibrous tissue, the separate fibres being only very loosely bound together, so that when a tendon is torn or cut they separate easily and the end of the tendon is apt to become frayed The longitudinal arrangement of the fibres gives a very poor hold for any suture that is passed through the tendon, and for this reason special methods of suturing have to be adopted At the proximal muscular end the strands of fibrous tissue continue either into fibrous septa in the muscle or sometimes into a flat fibrous layer upon the surface of the muscle The muscle fibres are inserted into these fibrous layers or septa At the distal end the tendon passes into and is continuous with, the periosteum of the bone A torn tendon may pull away from the muscle fibres at the upper end, it may rupture at its narrowest point, or it can be torn away from its insertion into the bone, usually carrying a flake of bone with it The particular injury depends on anatomical factors and upon the way in which the force acts The tendo Achillis most often ruptures at its narrowest point about 1½ inches above its insertion The quadriceps tendon ruptures just above its insertion into the patella The extensor expansion on the back of the fingers may separate from its insertion into the last phalanx or may pull away with it a small fragment of the phalanx The flexor tendons of the fingers have been known to tear right out of the muscle

Most tendons lie in a smooth sheath which is reflected over the tendon itself, so that the latter is suspended in its sheath by a meso-tendon The latter may be complete as, for example, in the tendo Achillis which is suspended in its sheath by an anterior meso-tendon right down to its insertion in the heel Or it may be incomplete, as in the flexor tendons of the fingers, considerable lengths of which lie perfectly free in the sheath without any attachment at all The blood supply of a tendon is derived from longitudinally disposed vessels which enter it from the muscle above, but an accessory supply may enter through the meso-tendon

In all operations on tendons it is important to avoid unnecessary injury to the sheath and the meso-tendon and to suture the sheath when it has been divided, if this is possible, without making it unduly tight Some tendons run in a direct line from the muscle to the

insertion, for example, the tendo Achillis Others pass around bony prominences and alter their direction, in this case they lie in a groove in the bone which is covered by a part of the tendon sheath, the canal for transit of the tendon being completed by a strong external fibrous layer An example of this is the passage of the peroneal tendons round the external malleolus Other tendons, particularly those on the flexor aspects of the limbs, alter the direction of the pull at the level of the joints that they pass this is carried out by passing the tendons beneath strong fibrous ligaments which prevent them jumping out of their grooves In front of the wrist the anterior annular ligament forms in this way a bridge beneath which the flexor tendons to the fingers are enclosed, and in the same way there is a fibrous bridge opposite the metacarpo phalangeal and the inter-phalangeal joints of all the fingers These fibrous bridges or fibrous canals over a bony groove should be respected and left undivided if the operation can be completed satisfactorily without interfering with them But if they must be divided they should be repaired by suture, because any permanent damage to them means serious interference with the function of the tendon Adhesion of a tendon to its sheath interferes with the action of the tendon as much as a complete division In those tendons which are not enclosed in bony or fibrous canals adhesions will very often gradually stretch and free themselves But in tendons which have to pass through such canals or have to work under a fibrous bridge, adhesion is usually very serious and permanent Thus, the tendo Achillis or the biceps femoris tendon will free themselves from adhesions, the extensor tendons of the fingers can also work themselves free, unless they are adherent in the region of the posterior annular ligament but if the flexor tendons of the fingers become adherent they almost invariably lose their function completely

TENOTOMY

Tenotomy consists in division of the tendon of a muscle, a gap being left that becomes filled with fibrous tissue from which the tendon is reconstituted and lengthened to an extent regulated by the gap that has been preserved during the process of healing It has been shown experimentally that when a tendon is divided *inside its sheath* the proximal end retracts, owing to contraction of the muscle The space left becomes filled with an effusion of blood, which within a few days begins to organize by the invasion of fibroblasts from the tendon-sheath New fibrous tissue then gradually replaces the clot and becomes adherent to the extremities of the tendon This fibrous tissue gradually organizes and, as it does so, contracts The extent of the contraction depends upon the position in which the part is held during the process of organization, for example, if the tendo Achillis has been divided and the foot is held in plantar flexion during healing, the ends of the tendon are approximated, the gap is small, and the fibrous tissue may contract to such an extent that there is actually no eventual lengthening If, on the other hand, the foot is strongly

dorsiflexed, or if the patient is allowed to walk upon the limb freely, so that the weight of the body forces dorsiflexion, the gap may be large, the fibrous tissue has little chance of contracting, and the tendon is lengthened to an extent which may leave a calcaneus deformity. The position of the part and the extent to which the tendon is stretched during the process of healing are, therefore, all-important in securing an eventual accurate correction of the deformity for which the tenotomy has been performed. Experiments show that about six weeks are required to enable the new fibrous tissue to become strong enough to withstand tension and to undergo its maximum of contraction. At the end of this time the strands of fibrous tissue have assumed a generally longitudinal direction similar to that in the original tendon. A tendon is very apt to adhere to its sheath at the point at which it is divided, and this becomes more likely in proportion to the damage done to the sheath. In tenotomy, therefore, it should be the rule to avoid injury to the tendon-sheath as far as possible, and to divide the tendon at a site where adhesion to the sheath will matter least. If two or more tendons run in parallel sheaths, e.g. the peroneus longus and peroneus brevis, the tendons should not be divided at the same level, because it is very probable that the cut ends will become adherent and the two tendons will cease to have any separate action.

Subcutaneous tenotomy.—In subcutaneous tenotomy the limb is so held as to place the tendon slightly on the stretch. A sharp tenotome is inserted through the skin, the blade of the knife being at right

Fig. 52a.—Jones's tenotome.

angles to the skin surface, with its flat surface parallel with the line of the tendon. The tendon being slightly relaxed, the tenotome is passed deep to it, far enough to make sure that it reaches across the under-surface. The tenotome is then turned so that its cutting edge is against the tendon, which is now placed on the stretch and cut through by slight sawing movements of the knife. As soon as the last strand has been divided, the tenotome is turned back to its initial position and withdrawn.

The best form of tenotomy knife is that shown in Fig. 52a, and known as Jones's; the blunt-pointed tenotome formerly used has now been universally discarded.

In many cases a so-called tenotomy consists in the division of a structure which is partly tendinous and partly muscular, or even entirely muscular. Thus, in tenotomy of the sterno-mastoid the sternal head is tendinous, the clavicular head largely muscular. In tenotomy of the adductors in the thigh the adductor longus is the only part which consists of tendon; the rest of the structures divided are muscular.

The subcutaneous division of a muscle with the tenotome is carried

out in exactly the same way as for a tendon In a few cases it is convenient to pass the tenotome between the structure to be divided and the skin, and to cut inwards into the tendon instead of cutting towards the surface

Open tenotomy.—It is inadvisable to practise subcutaneous tenotomy on certain tendons, either because there are structures in the neighbourhood which may be damaged by the operation or because there is a risk of lengthening the tendon too much unless the operation is done under the guidance of the eye In open tenotomy the incision is made in the line of the tendon, the tendon sheath is opened and a flat director (a hernia director is the best instrument) passed beneath the tendon, which can then be divided on this director with an ordinary scalpel If it is necessary to lengthen the tendon by a definite amount,

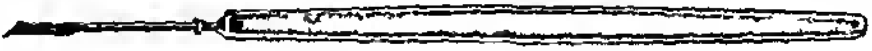

Fig 52b—Another type of Tenotomy knife

the tendon is split longitudinally for a distance of at least 1 in more than the amount of lengthening actually required (p 161) Each half of the split tendon is cut through on one side at the extremities of the split, the two halves are then allowed to slide upon each other to the required extent and are sutured together with two or more sutures of fine thread (No 60) After an open tenotomy or tendon lengthening, the sheath should be sutured at a few points with fine catgut and the skin sewn up in the ordinary way, but taking great care that the subcutaneous tissue is brought well together

After most tenotomies the limb requires fixation either on a splint or in plaster of Paris in that position which keeps the tendon stretched just to the required extent, and this position must be maintained for six weeks

Special Tenotomies and Myotomies

The sterno-mastoid—Tenotomy of the sterno mastoid is carried out for the correction of ' congenital torticollis In spite of its name, this condition is seldom noticed in the infant When it is discovered in the first year it will generally yield to treatment by massage and stretching but when discovered later than this tenotomy is required Children are most often brought for treatment between the ages of 5 and 7 Operation should be carried out as soon as the condition is discovered, as secondary changes in the cervical spine develop and facial asymmetry arises It has been the custom to recommend that the sterno mastoid should always be divided by an open incision, because (1) vessels, more particularly the anterior jugular, the external jugular, and the communicating twig between them are liable to injury, and (2) by a subcutaneous operation the complete division of the tendon and muscle and of its sheath of cervical fascia is impossible After division of the muscle this sheath of fascia

often remains tight and maintains the deformity If the open method is adopted, the incision should be made vertically over each head of the muscle, the skin retracted, and the muscle picked up and divided A subcutaneous suture in the layer of fascia containing the platysma should always be used, as otherwise a spreading of the scar in the skin or a cheloid scar is very likely to arise A transverse incision leaves a scar which is less noticeable, but the division of the platysma is likely to lead to a spreading of the scar or to a cheloid

This open division of the sterno mastoid has two serious objections The operation for torticollis is almost purely an æsthetic one, so that any result which leaves an evident scar is objectionable Moreover,

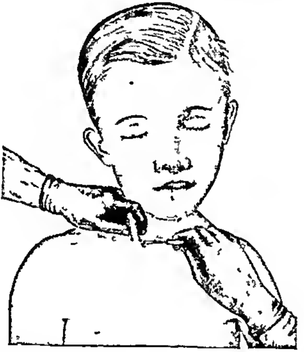

Fig 53 —Subcutaneous division of sternal head of sterno mastoid

the complete division of the muscle which is carried out in an open operation may entirely deprive the muscle of its attachment, so that the line which it shows in the normal neck is abolished on the side of operation The cosmetic effect of this is bad, and the deformity may actually be more noticeable than was the previous contracture For these two reasons subcutaneous tenotomy, followed by careful after treatment, is preferable

The subcutaneous operation (Fig 53) can be carried out with perfect safety, but instruments for performing the open operation should always be at hand, so that in case of hæmorrhage an incision can be made to pick up the bleeding point Such an incision will scarcely ever be necessary in the hands of an experienced operator For the subcutaneous operation the patient should lie on the back

with the shoulders resting on a sand-bag. Good anæsthesia is essential; cyanosis will certainly lead to hæmorrhage, which may be embarrassing. One assistant grasps the two arms just below the shoulders and pulls them downwards. Another assistant holds the head and manipulates it in such a way as to make the muscle to be divided stand out. In order to do this, the head must be held in a straight line with the trunk, and pressed laterally towards the affected side, the face then being rotated towards this side, and the chin depressed. The operator stands on the right-hand side of the patient. For the right sterno-mastoid, the tenotome is inserted on the medial aspect of the sternal head, passed deep to this, and the tendon divided from within outwards; the tenotome is then re-inserted between the sternal and clavicular heads, passed deep to the clavicular head, and this part divided. For the left sterno-mastoid, each muscle head is dealt with from the outer instead of from the inner side. When the muscle has been divided, the operator should complete the operation by himself taking charge of the head and putting it through movements which will fully stretch the affected sterno-mastoid. This will usually result in the cracking of a few bands, either of muscle or of fascia, which have been incompletely divided with the tenotome.

If the operation is carried out as described, the anterior jugular vein is situated too far forward, and the external jugular vein too far back, to come into the area of danger. The communicating vessel between the two, lying underneath the sterno-mastoid, is usually small and is only liable to injury if the tenotome is passed rather deeply. If there is a moderate amount of venous hæmorrhage, suggesting the division of a larger vessel than usual, it can practically always be stopped by holding a pad of gauze over the spot and pressing well down on to the clavicle.

After-treatment is usually carried out by starting massage stretching exercises and remedial exercises after four days' rest. The essential movements during the first six weeks are those which will fully stretch the affected muscle, e.g. lifting the patient by the head. Suspension by means of a Sayre's sling with the back resting against an inclined plane (Fisher's suspension bed) for half to one hour each day for a period of eight weeks is also useful. The fixation of the head in an over-corrected position by plaster of Paris or by some apparatus is exceedingly difficult and very irksome. A completely satisfactory cosmetic result can be attained by a competent masseuse without such fixation. If the operation is carried out after the age of ten, the secondary scoliosis may not be completely corrected and the facial asymmetry may persist.

Myotomy for flexion of the hip-joint.—In old-standing cases of infantile paralysis there is often a severe flexion and abduction contracture at the hip-joint. The contracted structures are the sartorius, tensor fasciæ femoris, anterior part of the gluteus medius, rectus femoris and front of the capsule of the hip-joint. The ilio-psoas

may also be shortened Attempts should always be made to overcome this contraction by extension manipulation and stretching without operative interference If these fail it may suffice in mild cases to pass a tenotome between the skin and deep fascia immediately below the anterior superior iliac spine and to cut inwards dividing the attachments of the sartorius tensor fasciæ femoris and fascia lata

In more severe cases an open operation is required An incision is made along the anterior third of the crest of the ilium turning down along the outer border of Scarpa s triangle The iliac crest is exposed and the anterior margin of the sartorius defined The attachment of this muscle is removed from the anterior superior spine and the fascia lata and tensor fasciæ femoris are divided at their attachments to the iliac crest The structures attached to the ilium are then stripped down towards the hip joint until the tendons of the rectus femoris are reached These are detached and the capsule of the hip-joint exposed It may be necessary to divide this vertically While the operation is being performed the shortened structures may be rendered tense by fully flexing the opposite hip to control the position of the pelvis The detached muscles and fascia are not sutured but are allowed to lie free and form re attachments at a lower level with intervening fibrous tissue

This operation tends to make the anterior part of the crest of the ilium rather prominent To avoid this the abdominal muscles may be stripped from this part of the crest and the bone bevelled down

After treatment may be carried out either by continuous extension in an adducted position the patient being fixed on his back on a bed or a Thomas s frame or lying on his face with the pelvis strapped down or by a forcible correction of the deformity at the time of the operation and the fixation of the pelvis and the limb in plaster of Paris If too forcible correction is attempted a fracture of the neck of the femur may very easily be caused This accident is not necessarily unfortunate as fracture of the neck of the femur or an osteotomy at this spot may prove to be the best means of correcting the deformity

Tenotomy of the adductors—Tenotomy of the adductors of the thigh is most often required in spastic paraplegia or hemiplegia It may also be carried out for adduction deformity resulting from any form of arthritis of the hip and it is often desirable as an accessory in osteotomy of the upper end of the femur and in arthrodesis of the hip It may be performed subcutaneously the tenotome being passed under the adductor longus tendon and band after band of this muscle of the adductor brevis and of the gracilis divided the limb being held abducted The division is carried out until a sufficient range of abduction is easily obtained The operation may be performed by an open method through a small incision over the adductor longus tendon

Tenotomy of the hamstrings—Tenotomy of the hamstrings may be required in spastic paraplegia and in all sorts of fixed flexion deformity of the knee whether from infantile paralysis or from old

disease of the knee-joint, or other cause. The tenotomies are carried out by the open method through two longitudinal incisions, one on the outer side over the biceps tendon, the other on the inner side over the tendons of the *semitendinosus* and *gracilis*. Each tendon in turn is picked up on a director, and either divided completely or split longitudinally and lengthened, the biceps being divided through the outer incision, and the semimembranosus, semitendinosus and gracilis through the inner incision. The lengthening operation is always to be preferred. The deep fascia must be sutured separately to prevent adhesion of the cut tendons to the skin. Subcutaneous tenotomy of the hamstring tendons is not a safe procedure, because of the vessels and nerves in the popliteal space. This applies particularly to the

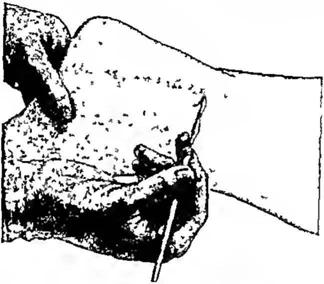

Fig. 54 —Tenotomy of tendo Achillis.

biceps, which lies close to the external popliteal nerve. The ilio-tibial band is often an accessory in maintaining fixed flexion of the knee. It may be divided subcutaneously with a tenotome immediately above the external condyle of the femur.

Tenotomy of the tendo Achillis. (Figs 54, 55.)—Tenotomy of this tendon is usually performed subcutaneously by a lengthening operation. In this method the tenotome is first inserted on the inner side of the tendon close to its insertion into the os calcis, passed between the tendon and skin, and by cutting from without inwards the inner half of the tendon is divided. The tenotome is then withdrawn and re-inserted upon the outer side of the tendon, about 1½–2 in. (in an adult) higher up the limb. The outer half of the tendon is divided at this level, the foot being held dorsiflexed, and the cutting continued until the tendon begins to give way. The tenotome is then withdrawn, and a little steady pressure on the foot will cause the two halves of the tendon to slide on each other. This dorsiflexion is carried

out to just that degree which gives the amount of lengthening of the tendon that is required, and the foot is fixed in plaster of Paris or on a splint. The actual distance between the points at which the tenotome is entered should always be considerably more than the lengthening required.

This subcutaneous lengthening has advantages over complete division of the tendon, the chief being that the amount of lengthening can be accurately adjusted. The tendon must not be stretched too far; after this sliding operation it has no power to shorten again, and

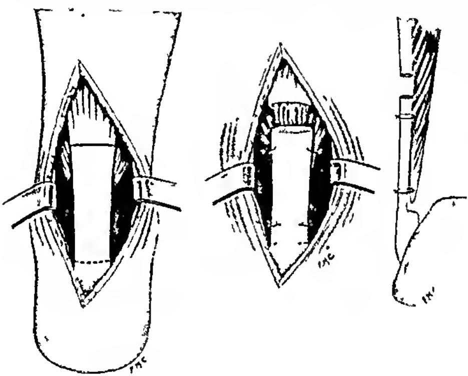

Fig. 55. Result of lengthening tendo Achillis by sliding operation. Diagrammatic.

The tendon is completely divided and separated from the underlying muscle to which it is re-attached at a lower level.

any excess of lengthening will be permanent and leave a calcaneus deformity. In small children the subcutaneous lengthening operation is not possible, and a complete division must be carried out.

The tendo Achillis may be lengthened by an open method, an incision being made either vertically over the tendon or a little to one side so that the scar is less prominent (Fig. 55). Open division is advocated by some surgeons in all cases of spastic contraction of the tendo Achillis, and may be required in other cases for special reasons, such as an excessively short tendon, or adhesions of the tendon to its sheath. After open tenotomy the sheath of the tendon should always be sutured separately.

Tenotomy of the tibial muscles.—The tibiales posticus and anticus are sometimes divided in cases of talipes varus This operation should always be carried out through a small incision, first, because it is impossible otherwise to make sure of dividing the tendon, and secondly, because other structures are liable to injury In dividing the tibialis posticus tendon, the posterior tibial artery or the flexor digitorum longus may be cut, and in dividing the tibialis anticus the extensor hallucis may be cut and may leave a permanent dropping of the great toe The tibialis posticus is best divided just above the internal malleolus, the tibialis anticus just below the annular ligament of the ankle

Tenotomy of the peronei.—The peroneal muscles are sometimes divided in spastic talipes valgus The operation should be carried out through an incision over the course of the tendons as they lie on the postero external aspect of the fibula just above the external malleolus The sheath of each tendon should be opened separately and the tendons divided at slightly different levels In some cases of spastic talipes valgus an actual exsection of from ½–1 in of each of these tendons may be carried out with the object of preventing union and consequent recurrence of spasm

Tenotomy of extensors of the toes.—This tenotomy is carried out on the dorsum of the foot over the heads of the metatarsal bones For the second to the fifth toes the operation may be done subcutaneously, the tenotome being slipped under the tendon which is divided by forcibly flexing the toe For the great toe it is better to perform an open operation and lengthen the tendon as a complete division may result in non union and a permanent dropping of the last phalanx

Tenotomy of the plantar fascia.—In so-called tenotomy of the plantar fascia the tenotome is entered on the inner margin of the sole, about 1 in in front of the tubercle of the os calcis, is passed across the foot between the skin and the plantar fascia, and turned and the fascia and structures adjoining it are cut from without inwards It is probable that, in addition to the plantar fascia part of the muscles of the sole particularly of the abductor hallucis is divided The operation is performed for pes cavus and correction of the deformity will necessitate either immediate wrenching of the foot with a Thomas s wrench or subsequent treatment upon a Scarpa s shoe

Steindler's operation.—This operation is a substitute for tenotomy of the plantar fascia which is sometimes followed by the production of a tender mass of new fibrous tissue which may persist for some months and is very apt to contract, so that the cavus deformity recurs This objection to tenotomy derives added force from the fact that, in a subcutaneous operation, other structures which hinder correction of the pes cavus cannot be divided, viz the short muscles of the sole, particularly the abductor hallucis, flexor brevis digitorum, flexor accessorius, abductor minimi digiti, and the long and short plantar ligaments In Steindler's operation the attachment to the

plantar fascia of all the muscles named above, and of the long and short plantar ligaments is separated from the under-surface of the os calcis and allowed to slide forwards, so that the sole is thoroughly flattened. A tourniquet should be applied, the foot held on its outer side on a sand-bag, and an incision made reaching from the inner side of the heel forwards, parallel with the inner border of the foot, as far as the level of the midtarsal joint. This incision is ¾ in. above the margin of the sole. It is carried down to the os calcis posteriorly and anteriorly until the plantar fascia and attachment of the abductor hallucis are seen. A flap consisting of the skin of the under-surface of the heel and subcutaneous tissue is lifted downwards, the skin of the sole being undercut to free it from the plantar fascia. With a knife, the abductor hallucis and plantar fascia are separated from the bone, and by working the outer side of the foot the abductor minimi digiti is similarly separated. With a sharp elevator the rest of the muscular attachments are then lifted from the whole nf the under-surface of the os calcis. The long and short plantar ligaments may come off with the muscles; if they do not, they should be divided with a knife, keeping close to the bone. The elevator must be worked forwards until it actually enters the calcaneo-cuboid joint. On the inner side, the abductor hallucis must be cut free from its attachment to the inner aspect of the os calcis and the internal annular ligament. Comparatively slight wrenching of the foot into a dorsiflexed position will then flatten out the sole completely. The wound can be sutured without removing the tourniquet, hæmorrhage being controlled by pressure over the dressing.

The operation was originally performed through the outer side, but this does not give so good an exposure. The incision must not be carried completely round the heel, or sloughing of the flap may result.

After-treatment is carried out by fixation at the time of operation upon a flat metal plate; at the end of four days this plate is removed, and the foot stretched daily. As soon as the wound is healed, the patient may walk, being particularly instructed to throw the weight well on to the fore part of the foot and thus continue the stretching. Alternatively, the foot may be wrenched until it is flat, and fixed in plaster of Paris for six weeks.

TENDON SUTURE

When one or more tendons have been divided, their suture by operation presents a problem which is by no means so straightforward as would at first appear. The suture of any individual tendon is difficult because the longitudinal arrangement of the fibres makes any stitch very apt to tear out if tension is put upon it. If the tendon has been ruptured, its ends are nearly always frayed and the insertion of sutures is even more difficult. The extremity of the cut or ruptured tendon very soon becomes sealed over with organizing blood clot, and at the end of 10-14 days from the date of the injury there will usually be a

slightly thickened bulbous end which may be loosely adherent but which can be handled much more easily than the friable cut or ruptured surface, found when operation is performed at the time of the injury.

Suture of a tendon should not be considered a minor operation It should always be carried out under the best possible conditions, with adequate preparation, in a good operating theatre, and with proper assistance If these are not available *it is better to treat the* wound by cleansing excision of the damaged tissue and suture, leaving the reconstruction of the injured tendons until later It is, in any circumstances a mistake to attempt immediate suture except in a clean incised wound The slightest infection is almost certain to give rise to adhesions which will interfere with the subsequent action of the tendon

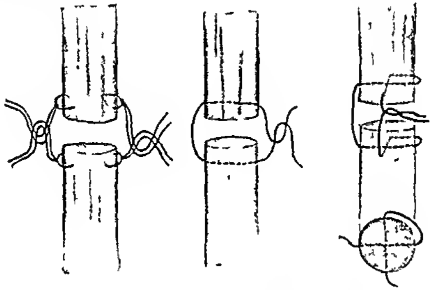

Fig 56 —Three methods of suturing tendons

If the wound heals aseptically, secondary suture of the tendon can be carried out at the end of a fortnight If it does not, the secondary suture must be postponed until the wound is soundly healed and all scar tissue around *the tendon must be excised at the operation*

When a tendon has been divided the proximal end retracts and there may be a considerable gap For example, if a flexor tendon of one of the fingers is divided in the palm the proximal end may retract to above the level of the annular ligament A small longitudinal incision should be made at the site of the injury and the distal end found, if the proximal end is not thus made visible, a separate incision should be made in the line of the tendon above the annular ligament and the tendon identified and freed A suture is then inserted in its extremity, and by passing the end of the thread along the sheath beneath the annular ligament the tendon can be drawn down until it meets the distal end A similar method should be adopted, when

possible, if the tendon is divided opposite one of the phalanges and the proximal end has retracted into the palm. The tendon should be relaxed as much as possible by position; for example, by flexing the wrist and fingers in the case of the flexor tendons of the hand, by extending them in the case of the extensors. In freeing a tendon and bringing it into position for suture, the greatest care should be taken to do as little damage as possible to the surrounding tissues and to the meso-tendon. In suturing a tendon which has been recently divided, none of the tendon should be cut away; in suturing one which has been divided long enough for a bulbous end to have formed, the surface of the bulb should be pared so as to leave a raw area. The best suture material is linen thread, No. 60 being used for all small tendons and No. 40 or 20 for large tendons such as the tendo Achillis and the tendon of the quadriceps. Catgut and kangaroo tendon, being prepared with chemicals, are irritating and more apt to produce adhesions. Methods of suturing are shown in Figs. 56 and 57. It is useless to surround a sutured tendon with any form of artificially-prepared membrane. Such substances, far from preventing adhesions, cause increased fibrosis by acting as foreign bodies. When the tendon possesses a sheath this should be allowed to fall into place and be sutured with fine catgut, if this is possible without making it unduly tight, but it is often best simply to leave the sutured tendon free and to allow it to be covered by the surrounding fat. Tendons undoubtedly work themselves free most easily when they lie in fatty tissue. An example is seen in cases of tendon transplantation in which the tendons have been transferred to their new position through the subcutaneous tissue.

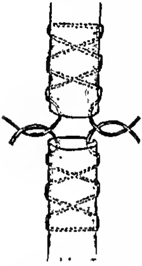

Fig. 57.—Method of suturing tendons. A separate thread is passed backwards and forwards through each end of the tendon. The two ends of the thread projecting from the end of the tendon enable the latter to be pulled upon without fear of the thread cutting out.

After suture of the wound the part should be fixed in a position which relaxes all tension on the divided tendon, and this position must be retained for six weeks. Any tension upon the tendon during this time is almost certain to cause re-rupture or over-stretching. The prognosis in cases in which tendons have been sutured depends upon the tendon divided and the point of division as well as upon the success and cleanliness with which it has been sutured. The extensor tendons of the wrist and fingers and of the toes, the tibial tendons, peronei and tendo Achillis all give a good prognosis. But the flexor tendons of the fingers and toes do not do well. In fact the flexor tendons of the fingers and thumb seldom recover proper function when they have been divided distal to the annular ligament. Divisions of the flexor tendons of the wrist and of the fingers above the annular ligament do better.

After six weeks the injured part should be treated by massage, faradic stimulation of the muscles, and exercises to restore functional use but even after this time, care should be taken that no undue strain is put on the tendon At the time of operation an extreme position has often to be adopted in order to relax tension upon the tendon If this position is retained for the full six weeks it may be difficult to correct it subsequently It is therefore advisable to alter the splinting gradually after three weeks For example, if after suture of the tendo Achillis the foot has been fixed in a position of full plantar flexion in plaster of Paris, at the end of three weeks the plaster is cut and its posterior part used as a splint which can be padded under the fore part of the foot, which is thus gradually dorsiflexed up to the right-angled position The upper limb may be used at the end of six weeks but the lower limb should not be used until mobility has returned Thus after suture of the quadriceps tendon, the patient should only be allowed to walk with a splint on the knee until flexion up to the right angle has been restored and in the case of the tendo Achillis he should only walk upon the foot when it will dorsiflex to the right angle If this principle is not adhered to, a sudden strain may overstretch or re-rupture the tendon

RECONSTRUCTION OF TENDONS

In a tendon which has been damaged some time previously, there may be found a considerable gap between the ends, or such a gap may be left when the tendon has been dissected free from adhesions, and it may be impossible in consequence to bring the ends into sufficiently close apposition for suture In this case an attempt may be made to reconstruct the tendon by a strip of fascia or by another tendon In reconstructing a tendon with fascia a strip of sufficient width is removed from the fascia lata, one end of this is fixed to the distal end of the tendon by passing it through a small hole in the latter and suturing proximal and distal to this aperture The other end of the fascia is then sutured to the proximal end of the tendon in a similar manner, with sufficient tension to bring the joints into the position in which they lie when the muscle is contracted In some cases, instead of attempting to reconstruct a tendon, it may be advisable to utilize a neighbouring tendon to carry on the function, for example, in the case of the peronei if one tendon is intact and the other missing, the proximal and distal ends of the damaged tendon may be sutured to the sound one so that the two muscles act as one

TENDON-TRANSPLANTATION

In tendon-transplantation the insertion of a muscle is altered in order to restore some lost function, or in order to alter the balance of muscles in one or more particular groups For example, in transplantation of the flexor carpi radialis into the extensor muscles of the thumb, the object of the transplantation is to restore the power of

active extension and abduction In transplantation of the tendon of the tibialis anticus to the cuboid an endeavour is made to correct the balance of the muscles on the extensor aspect of the foot converting a muscle which was an invertor of the foot into an evertor but leaving it with its original action of dorsiflexion

In planning transplantation of tendons certain broad principles must be observed —

1 It must be possible to spare the transplanted muscle from its original action
2 It must be possible to bring the tendon in a straight or fairly straight line to its new point of attachment
3 The transplanted muscle must be strong enough to carry out its new work
4 The transplanted muscle must be capable of re education so that it may carry out its new function

The last of these points requires further consideration as many failures are due to a lack of consideration of the possibility of educating the nerve centres to carry out the movement required from the trans planted muscle It must be remembered that centres of voluntary movement represent particular movements rather than particular muscle actions in other words when the message from the cerebral centre passing to the anterior tibial group of muscles directs them to dorsiflex the foot it does not direct any individual muscle to contract It is therefore extremely difficult to re educate the nerve-centre in such a way as to produce dorsiflexion of the foot by a muscle which is normally a plantar flexor Probably for this reason transplantation of the peroneus longus (which is a plantar flexor) across the front of the foot to the inner side is a failure because in the new position the peroneus longus is a dorsiflexor and it will refuse to work automatically in common with the other dorsiflexors In the upper limb individual re-education is easier because movements of the wrist and hand are more definitely voluntary and purposive than are those of the foot When the pronator radii teres is transplanted into the extensors of the carpus it is not difficult to teach the patient that by attempting to pronate his forearm he will extend the wrist A common trans plantation is to transfer one or other of the flexors of the carpus into the extensors of the fingers In this case the transplanted muscle is one which normally acts synergically with those muscles into which it is being transplanted for when the extensors of the fingers are in action the flexors of the wrist are at the same time contracting in order to keep the wrist fixed Re-education of movement is therefore comparatively easy

One further point in transplantation is important Physiological investigation tends to show that certain muscles which are used in maintaining the erect position have a special form of continuous activity which has been named postural activity This form of action is most highly developed in such muscles as the erector spinæ

glutei quadriceps extensor femoris and those of the calf It consists of a continuous tonic contraction which in other muscles would produce rapid fatigue and it is probably produced by a special nervous mechanism The transplantation of other muscles into this group is likely to fail particularly if opposing muscles are selected For this reason transplantation of any one of the hamstrings into the quadriceps extensor femoris has universally proved a failure

The following general principles of technique for transplanting a tendon may be laid down —

1 The tendon should be divided at a point which allows of a length ample for the tendon to reach its new destination This may or may not mean that it has to be taken at its insertion It is very inconvenient to divide some tendons close to their insertions in the case of other tendons e g tibialis anticus it is essential to do so

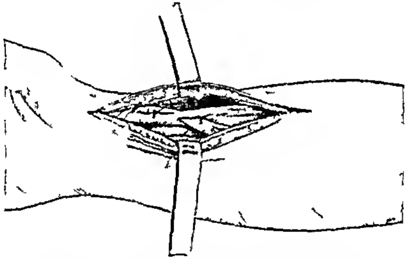

Fig 58 —Transplantation of tendon by passing it through aperture in recipient tendon and suturing it at point of perforation and beyond

2 When the tendon is being divided the surgeon should consider whether or not it is necessary to replace its action by attaching the distal end to some other tendon This is only occasionally necessary as for example in the case of the extensor longus hallucis The complete loss of action of this tendon leads to a drop of the last phalanx of the great toe

3 The transplanted tendon must be brought into proper line for its new insertion

4 It must be sutured under sufficient tension for example in transplanting the tibialis anticus to the outer side of the foot the foot must be held everted and the tendon stretched tight while the fixation is made In transplanting a carpal flexor into the extensors of the fingers the wrist and the fingers must be held dorsiflexed and both the transplanted tendon and the extensors of the fingers kept in moderate tension during the suture

5 The suture must be secure. Two chief methods are employed

(1) *Tendon into tendon*.—This is best carried out by leaving intact the tendon into which the transplantation is being made, and suturing the transplanted tendon into it by the method in which one tendon passes through a slit in the other and is sutured at the point of passage and beyond (Fig 58)

(2) *Tendon into bone*.—Either (*a*) a tendon is laid in a slit made in the periosteum and sutured to the latter, which is closed over it, or (*b*) the transplanted tendon is taken with a small piece of bone from its original attachment and this piece of bone is fixed in a bony groove cut at its new point of attachment, or (*c*) the bone is drilled at the new point of attachment, the tendon passed through the aperture and sutured back to itself

Special Transplantations

Transplantation for musculo-spiral paralysis.—In complete musculo spiral paralysis in the forearm, the functional disability can be remedied to a large extent by tendon transplantation The object of the transplantation is to restore the ability to extend the wrist-joint, and to enable the patient to extend his fingers and thumb and thus completely open his grip without the wrist at the same time becoming flexed The operation now usually performed is carried out as follows

An incision is first made on the radial side of the middle of the forearm Through this the tendons of the extensor carpi radialis longior and brevior are exposed cleared, and lifted backwards, the supinator longus being displaced forwards Under cover of these muscles the tendon of the pronator radii teres is found attached obliquely to the radius This is lifted off the shaft of the bone by cutting along each side of it and stripping with a periosteal elevator A Kocher's forceps is fixed upon each radial extensor in the upper part of the wound, and the tendons of these muscles are pierced with a knife at a slightly lower level The tendon of the pronator radii teres is then passed through the openings in the two extensor tendons An assistant keeps the wrist extended and tension upon the distal extremities of the two extensor tendons by pulling upon the Kocher's forceps The tendon of the pronator radii teres is then stitched to the extensor tendons at the points at which it pierced them a fine curved needle threaded with No 60 thread being used At least two stitches should be inserted in the tendon and if there is sufficient length of pronator radii teres available, a further suture should be made between this tendon and the extensor carpi radialis brevior beyond the point at which it pierces the latter This wound can now be sutured A second and smaller incision is made in front of the middle of the wrist, the flexor carpi radialis tendon being divided close to the annular ligament Through another small incision in the middle of the front of the forearm this tendon is pulled out with a hook. A fourth incision is made up the ulnar border of the front of the forearm The tendon of the flexor carpi ulnaris is cut close to its attachment to the pisiform bone, and the muscle is stripped from the

ulna for 3 in up the forearm A curved incision is made at the back of the wrist, extending from the middle line to the radial border, and thence for 1½ in up the radial side of the forearm Through this the extensor ossis metacarpi pollicis, extensor brevis pollicis, extensor longus pollicis, extensor communis digitorum and extensores indicis and minimi digiti are identified and cleared above the annular ligament at the back of the wrist A long fine pair of Kocher s forceps is passed through this incision subcutaneously, first to the incision in the middle of the front of the forearm, and the tendon of the flexor carpi radialis pulled through, and secondly to the incision on the ulnar border, the tendon of the flexor carpi ulnaris being pulled through The tendon of the flexor carpi radialis is then passed through slits in the tendons of the extensor ossis metacarpi pollicis and extensor brevis pollicis, the thumb being extended and abducted and tension made on all the tendons Suture is made as in the case of the pronator radii teres The flexor carpi ulnaris is passed from the ulnar to the radial side through the extensor minimi digiti extensor communis, extensor indicis and extensor longus pollicis tendons and sutured to these, the fingers being held fully extended The wounds are sutured, and the hand is fixed upon a long cock-up splint with the thumb abducted

Active movements may be commenced as soon as the wound is healed, provided the surgeon feels that his sutures are secure, but the splint should be maintained in place for six weeks for fear of any continuous or severe tension coming upon points of suture Re education will be required for only a few weeks afterwards, the patient's own efforts being almost sufficient

Transplantation for partial musculo-spiral paralysis.—This operation should not be done if the palmaris longus is absent One muscle must be left to act as a flexor of the wrist and the one transplanted must, therefore, be attached to the abductors and extensors of the thumb and to the extensors of the fingers It sometimes happens that only certain of the extensor muscles need to be replaced It may then be possible to transplant in such a way as to give individual control of particular movements A good example is an injury of the middle of the back of the forearm, involving paralysis of the three thumb extensors, but leaving intact the extensors of the carpus and the extensor communis digitorum In such a case the flexor carpi radialis, supinator longus, and extensor carpi radialis longior may be transplanted into the extensor ossis metacarpi pollicis, extensor brevis pollicis, and extensor longus pollicis respectively The technique of the operation does not differ essentially from that already described Re-education of individual movements of the separate joints of the thumb is possible after this operation

Transplantation of the sartorius into the quadriceps extensor cruris.—Various operations have been carried out for the relief of paralysis of the quadriceps extensor cruris muscle Reasons have already been given why transplantation of the hamstrings into the patella is a failure

The sartorius, on the other hand, does act synergically with the rectus femoris, and can be made to work as an extensor of the knee It must not be expected, however, that it will be strong enough to hold the knee from flexing further when the weight is placed upon the joint in the position of slight flexion The most that can be expected of a transplanted sartorius is that it will have sufficient power to swing the knee into an extended position in which it is stable without muscular activity

This transplantation should be made of muscle into bone A curved incision is made down the inner side of the thigh, round the inner border of the patella to the tubercle of the tibia and a flap of skin turned outwards The sartorius muscle is found in the wound, traced down to its tendon, and cut away from the tibia It is separated from the surrounding structures as far as 3 in above the upper border of the patella, and brought into fresh alignment with the anterior surface of the latter bone The periosteum on the surface on the patella is cut through vertically and stripped back, the tendinous part of the rectus being separated A groove is then cut in the anterior surface of the bone, and the sartorius laid in this groove and sutured to the rectus tendon and to the periosteum of the patella, the knee being kept fully extended A very secure suture can be established, and for this reason active movements may be commenced as soon as the wound has healed, but full flexion of the knee should only be allowed to come gradually at the end of six or eight weeks

Transplantation of the flexores longus hallucis and digitorum and of the peronei into the tendo Achillis.—Reinforcement of the gastrocnemius and soleus by transplantation of other muscles which are flexors of the foot is a useful procedure in talipes calcaneus It is, however, most often combined with fixation of the tendo Achillis, and often also with arthrodesis of the subastragaloid and midtarsal joints A long incision is made over the lower third of the back of the leg in the middle line extending right down to the back of the heel Through this the tendo Achillis is exposed and its sheath opened On the inner side an incision in the deep surface of the latter sheath will expose the tendon of the flexor longus hallucis as it winds round the groove in the astragalus This tendon is pulled up from the sole as far as possible the foot being plantar flexed, and the tendon divided at as low a level as can be reached The flexor longus digitorum is then sought farther forward in front of the posterior tibial nerve and vessels, and this also is divided as it enters the sole On the outer side the two peroneal tendons are similarly found and divided at the point at which they wind round the external malleolus A small incision is made in the centre of the tendo Achillis at the point at which it is attached to the os calcis Through this a pair of Kocher s forceps is pushed through to the deep aspect, brought out on the inner side, and the tendons of the flexor longus hallucis and the flexor longus digitorum are brought out through the tendon Similarly, the peronei are passed through it from the outer side Each tendon in turn is sutured with

fine thread to the deep surface of the tendo Achillis, and then beyond the opening in the latter to its surface The tendons are again sutured to the tendo Achillis, where it is attached to the *os calcis* The foot is held in the plantar flexed position, and each tendon drawn as tight as possible at the moment of suture The foot is fixed in the plantar-flexed position in plaster of Paris or on a splint, and this position maintained for a period of at least six weeks

Transplantation of the tibialis anticus into the 5th metatarsal.—In persistent paralytic talipes varus with paralysis of the peroneal muscles, this transplantation will often restore the balance between the invertors and evertors of the foot An incision is first made on the side of the foot over the base of the first metatarsal bone The lower part of the tendon of the tibialis anticus is cleared and its bony insertion cut away with a chisel, a small piece of the base of the first metatarsal being left attached to the tendon A second incision is made in the middle line of the leg just above the ankle joint, through this the tendon is pulled out with a hook A third incision on the outer side of the foot exposes the base of the 5th metatarsal bone and the insertion of the peroneus brevis Through this last incision a fine pair of Kocher s forceps is passed up subcutaneously to the incision above the ankle the track thus made dilated with forceps and the tendon of the tibialis anticus drawn down through it A small oblique incision in the periosteum of the metatarsal exposes the bone, in which a groove is cut with a chisel and in this groove is laid the bony fragment attached to the end of the tibialis tendon while the foot is held dorsiflexed and everted The tendon is then sutured to the periosteum of the metatarsal and to the peroneus brevis tendon with fine thread When the skin incisions have been sutured the foot is fixed in the dorsiflexed and everted position in plaster of Paris which is maintained for a period of six weeks

Transplantation of the extensor longus hallucis into the neck of the first metatarsal bone. (Fig 59)—This operation is often done for pes cavus with clawing of the great toe, which is hyperextended at the metatarso-phalangeal joint and flexed at the interphalangeal joint A straight incision is made extending from the head of the first metatarsal bone along its dorsal aspect in the line of the extensor tendon Through this the extensor longus hallucis tendon is exposed, cleared, and divided at the point

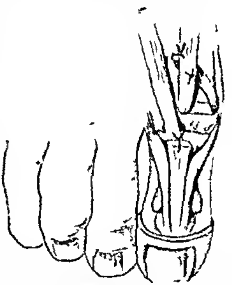

Fig 59—Transplantation of extensor longus hallucis into neck of first metatarsal bone by passage through tunnel in bone, distal end of tendon is sutured to extensor brevis

where it begins to expand as it passes to the base of the phalanx. This expansion should then be sutured to the tendon of the extensor brevis in order that the latter may prevent dropping of the terminal phalanx. The neck of the first metatarsal bone is cleared on its dorsal and inner aspects and drilled on these surfaces the two drill holes meeting in the medulla of the bone. The termination of the tendon is then doubly pierced with thread and the latter passed through the hole in the bone by a fully curved aneurysm needle the tendon being thus threaded through the neck of the first metatarsal bone. The end of the tendon is looped back and sutured securely at the point at which it enters the bone. The foot should be held in the dorsiflexed position for six weeks. The tendon of the extensor longus hallucis may be sutured in this way to any part of the shaft of the first metatarsal bone.

In pes cavus with bad clawing of the toes a similar operation may be performed on each metatarsal bone except the 5th where there is only one tendon right across the foot. Alternatively an incision may be made in the middle of the dorsum of the foot and the four tendons of the extensor communis passed through an opening drilled in the external cuneiform and sutured at this point (Hibbs's operation).

TENDON-SHORTENING AND TENDON-FIXATION

Shortening a tendon which is overstretched through paralysis is very unlikely to produce any permanent benefit. Practically the only conditions for which tendon shortening is useful are those in which the tendon has been ruptured or divided and has been allowed to unite without adequate support so that it is overlengthened—for example after traumatic rupture of the tendo Achillis which has been treated without fixation.

In small tendons shortening may be carried out by taking an actual fold of the tendon and suturing the edges together at two points. In a large tendon such as the tendo Achillis the best method of shortening is to make a Y shaped incision and to suture in the shape of a V so that the tendon is shortened by an amount equal to the vertical limb of the Y (Fig. 60). Afterwards fixation for six weeks is necessary as in any other tendon.

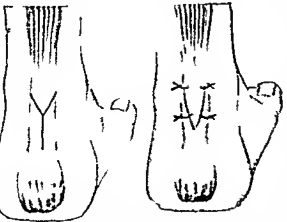

Fig. 60.—Operation for shortening tendo Achillis by a Y shaped incision converted by suturing into a V (Diagrammatic)

By tendon-fixation is meant the procedure by which the tendon of a muscle is separated from the muscle in whole or in part and is fixed directly to a bone so

that thereafter it acts as a ligament Fixation of the tendo Achillis for paralytic talipes calcaneus may be taken as an example For this operation a vertical incision is made over the lower third of the tendo Achillis in the middle line The tendon is exposed and cleared from its surroundings and a strip is separated from the rest of the tendon and muscle from a point about 1½ in above its insertion upwards as far as it consists of good strong tendinous fibres At this point it is cut through so that a strip of strong tendon ½ in broad is left attached below but free above The whole tendo Achillis is now retracted to the outer side the flexor longus hallucis under cover of it exposed and lifted from the back of the lower end of the tibia a vertical incision is made in the periosteum of the tibia and the bone cleared with an elevator Two separate drill holes are made into the medulla of the tibia as far apart as the width of the posterior surface of the bone will allow The strip of tendo Achillis is now passed through these drill holes by means of an aneurysm needle and a thread firmly attached to the extremity of the tendinous strip The foot is plantar flexed to an angle of 110 degrees the strip of tendon drawn tight passed through the small aperture in the main tendon as near as possible to its lower end and securely sutured there The sheath of the tendon and the skin are then sutured and the foot fixed in the plantar flexed position Fixation is maintained for a period of three months By means of this operation the strip of tendon used is converted into a posterior ligament which prevents dorsiflexion of the ankle The remainder of the tendon is left with its normal function if any active muscle remains

Fixation of the peronei —Fixation of the peronei may be carried out for paralysis of these muscles with persistent talipes varus It is not likely to be successful in infantile paralysis because the tendons are as a rule too much atrophied to take on the function of ligaments It may be however a useful operation in certain cases of traumatic paralysis of the musculo cutaneous part of the external popliteal nerve An incision is made over the fibular shaft in its lower third the bone is drilled and the tendons of one or both the peronei are cut away from the muscle passed through the opening in the bone drawn tight while the foot is held flexed and abducted and sutured securely to themselves

GANGLIA

Ganglia are of two sorts simple and compound The simple ganglia are found on the dorsal surfaces of the hand and foot and occasionally in the neighbourhood of joints for example of the knee joint and of the metatarso phalangeal joints of the big toe They consist of a thin fibrous sac with a lining of endothelial tissue and contain a clear glairy fluid Their operative treatment consists in a careful excision of the whole of the sac every portion of which must be removed search being made for outlying portions If any of the latter are missed the ganglion is almost certain to return

Ganglia are sometimes associated with cystic change in the synovial membrane of a joint, and really consist of protrusions of such synovial cysts—Morrant Baker's cysts They may be found at a considerable distance from the joint, and are then only connected with it by a narrow track Such ganglia are found connected with the metatarso-phalangeal joint of the great toe, with the knee-joint, and with the superior tibio-fibular joint If the connection with the joint is unrecognized the ganglion will recur after removal If it is recognized, it should be traced to the joint, which should be opened and the cystic synovial membrane removed

Compound ganglia are found usually on the flexor and extensor aspects of the wrist They are chronic inflammatory swellings of the tendon sheaths When such a compound ganglion, for example, on the dorsum of the wrist, is explored, it will be found that there is granulomatous material involving the tendon sheath and the meso-tendons and possibly infiltrating some of the tendons themselves All this inflammatory tissue must be dissected away carefully, right up to the tendon fibres It is best to do this through two incisions, one above, the other below, the annular ligament By pulling the tendons upwards and downwards the inflammatory tissue lying beneath this ligament can be removed without division of the ligament itself The tissue thus removed is sometimes found to be tuberculous, but in many cases it proves to be chronic granuloma of unknown cause After removal of a compound ganglion the wrist should be rested for five or six weeks until the wound is perfectly healed, but during this time the tendons themselves should be rolled gently in their grooves

CHAPTER VI

AMPUTATIONS

By the late R. C. ELMSLIE, O.B.E.

The object of an amputation is the removal of a limb or part of a limb, on account of an injury or disease. The level at which an amputation is carried out must, in the main, depend upon the condition of the parts to be removed, but in modern surgery it also depends upon the function desired in the remaining stump. This function differs in the upper and the lower limb.

In the lower limb the stump must be capable of bearing weight in standing and walking, either directly or through the intervention of an artificial leg or foot. In fact, in modern surgery the level at which an amputation of the lower limb is carried out and the method of amputating depends largely upon the possibility of supplying a good prosthetic appliance to the resulting stump. A knowledge of the methods of fitting artificial limbs and of their mechanics is essential to a proper consideration of the best methods of amputating.

In the upper limb the function of a stump is entirely different. It may itself be useful, either for supporting or for handling and moving an object, or it may be capable of use for the transmission of movement to an artificial arm, or to an appliance used instead of an arm. As a support for an artificial arm, the function of the stump is not to bear weight, but to transmit movement. The points of pressure are, therefore, quite different. In fact, the problems presented by amputation in the upper and the lower limb are entirely dissimilar, and must be considered separately.

If an amputation is carried out under such conditions that healing by primary union is almost certain, it is natural to suppose that the amputation which will remove the diseased or damaged part and will leave the best possible functional use in the remaining stump will be carried out immediately, so that no further surgical treatment of the stump is required. Such an amputation may be called a final amputation, and should be so designed as to give an ideal stump suitable in every way for a prosthetic appliance. The full rounded stumps which used to be considered so satisfactory are not now looked upon with favour by the artificial leg makers. As a result of the enormous experience following the 1914–18 War it has been found that a tapering stump with the bone end well covered by skin free from scar is much easier to fit with a prosthesis. If there is a possibility or a probability of sepsis arising in the amputation wound, secondary operations for

drainage removal of necrosed bone or re-amputation will very probably be required This may result in a shortening of the stump or in an interference with the position of scars and covering of the bone as originally designed Such an amputation may be called a primary amputation because it does not leave the stump in its final condition Amputations which are suitable for final operations are not necessarily suitable for primary operations and vice versa It will be most convenient to consider first those amputations which give the best functional stumps and which are therefore the ideal final amputations next to consider the methods of amputating as a preliminary measure in the presence of sepsis and finally to consider methods of re amputating where they differ from those already described as final amputations

AMPUTATIONS IN THE LOWER LIMB

In the lower limb it does not follow that the maximum possible amount should be saved Length of stump up to a certain point is an advantage beyond that point it may be only an embarrassment For example an amputation through the middle third of the leg is easily and comfortably fitted with an artificial limb An amputation through the lower third of the leg makes the bucket of the artificial limb clumsy and bulky round the ankle without giving any compensatory advantage In amputation at this level the end of the stump is nearly always cyanosed and tends to ulcerate There are therefore both mechanical and surgical reasons against the retention of any part of the tibia beyond the middle third unless the amputation can be carried out at the level of the ankle-joint

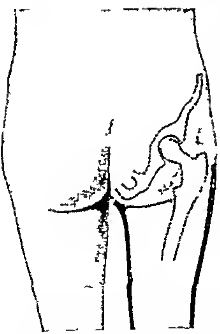

Fig 61 —Fitting of bucket of artificial limb for thigh amputation against tuberosity of ischium and great trochanter

An artificial leg carries the weight of the body transmitted through certain points termed bearing points Some stumps can transmit weight by direct pressure upon their extremity when this is possible the stump is said to be capable of *end bearing* In other cases the weight must be transmitted by pressure of the bucket of the artificial limb against the bone around the joint above the level of the amputation—that is to say in an amputation through the leg the bearing is taken upon the head of the tibia and lower margin of the patella (*tibial bearing*) In amputation through

the thigh the bearing is taken on the tuberosity of the ischium (*ischial bearing*) (Fig 61)

The factors which tend to render end bearing possible are —

1 A covering of skin which is accustomed to pressure such as the skin of the heel or the skin over the front of the knee
2 A division of the bone at a level where it is cancellous rather than at a level where there is a medullary cavity
3 A covering over the end of the bone of fibrous or areolar tissue, which forms a certain amount of padding

End bearing may be complete i e the entire bodyweight may be transmissible through the end of the stump or it may be partial the stump being capable of bearing only a part of the weight, the rest of which is transmitted through a tibial or ischial bearing End bearing is an important function in a stump so that amputations which yield partial or complete end bearing are to be favoured unless there are other contra-indications The skin in the regions upon which other bearings—tibial or ischial—are taken should if possible be sound and unscarred A painless linear scar over them does not matter, but an extensive and particularly an adherent, scar prevents a bearing being taken at that point A scar on the end of the stump is for this reason undesirable and this fact makes amputation by a single flap preferable to other methods

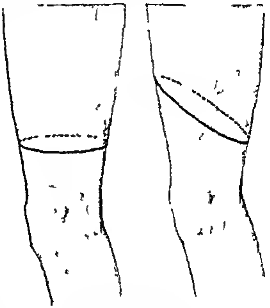

Fig 62 —Amputation by circular and oblique elliptic incisions

Flaps. (Figs 62 63 64)—The simplest form of amputation is the circular method in which the skin is severed by a transverse circular incision, retracted upwards a little the muscles and bone being cut directly across at a higher level Suture of such a flap will obviously leave a terminal scar In some cases such a method does not give a sufficient exposure The addition of a single longitudinal incision on one or other side of the limb allows better exposure, and converts a circular amputation into amputation by a transverse racket incision The addition of a second longitudinal incision on the opposite side of the limb produces amputation by equal antero posterior or lateral flaps Any of these again yields a terminal scar A second simple method of amputation is by an oblique circular incision extending lower on

one aspect of the limb than on the opposite aspect. This again may be converted into an oblique racket incision and into amputation by unequal flaps by the addition of one, or two, longitudinal incisions. Other fundamental methods of designing flaps are to cut unequal rectangular or semicircular flaps on the antero-posterior or lateral aspects of the limb, or to cut a single long flap from one-half the circumference which covers over the entire end of the stump. It has been generally stated that the total length of the flaps should be equal to one and a half times the diameter of the limb at the level of section of the bone. This rule appears to have been drawn up in the days of pre-antiseptic surgery and to have persisted long after it should have become obsolete. When a stump took a long time to heal by granulation, great retraction took place and long flaps were necessary. In amputations in which asepsis is secured the total length of the flap or flaps need never be more than the diameter of the limb at the point of section of the bone, and may, when the skin is supple and easily stretched—as in the thigh—be even shorter. In the final stump the aim should be to get the skin fitting snugly over the end without undue tension, but also without any redundancy or excessive mobility of the soft parts upon the bone. The desire to get a closely-fitting end to the stump, and a scar at the margin (either anterior, posterior, or lateral) leads to a preference for amputation by the single flap, the corners of which are rounded, and the length of which is not greater than the diameter of the limb at the point of division of the bone Directions for amputation often include the cutting of flaps by methods of transfixion of the limb, the knife cutting longitudinally down the limb and then being turned to come out upon the surface. Such a transfixion method is a relic of pre-anæsthetic surgery and was dictated by the desire to cut a flap in the shortest possible time. It is now quite obsolete. A flap should always be marked out carefully with the scalpel and dissected up as it would be in any other operation.

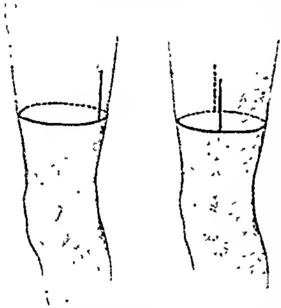

Fig. 63.—Amputation by transverse rackel and equal antero-posterior flaps.

There is some difference of opinion on the advisability of including muscles in the flaps used to cover the end of a stump. A flap which includes much muscle is certainly undesirable, and the attachment of

tendons into the flap should be avoided for, although the skin over the end of the stump should be mobile, there ought to be no possible active mobility On the other hand, in certain situations, if a flap is of skin only, the muscles being divided at the level of section of the bone, the muscles retract greatly, leaving a prominent bone end which makes the stump conical This is undesirable * The best rule is that the flap itself should consist of skin only but that in situations —as for example, in the thigh—where a conical stump is likely to arise, portions of some of the muscles should be preserved and sutured over the end of the bone so that they become adherent to it and cannot retract

Dealing with the bone and periosteum. — The bone must be divided accurately in a plane transverse to the longitudinal axis of the limb, so as to give a flat, level surface If the shape of the bone at the point of section leaves a prominent angle under the skin, this should be rounded off Considerable attention has been paid to methods of dealing with the periosteum and it is now generally recognized that it is best to leave the end of the bone bare The periosteum is divided circularly and stripped downwards The bone is then cut through at a lower level so that its last half inch is left uncovered by periosteum The end of the bone becomes slightly rounded and sclerosed, and where a medullary cavity is present, it becomes filled with a bony plug There is no production of new periosteal bone around and consequently no thickening and spur-formation If infection of the wound is probable, the periosteum and bone should be divided at the same level

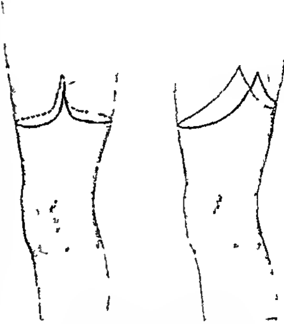

Fig 64 —Amputation by equal and unequal semi circular antero posterior flaps

Arrest of bleeding.—In all amputations except such minor ones as those of the toes and fingers a tourniquet should be used whenever possible As soon as the bone has been severed and the amputated part removed, the main vessels are picked up with Spencer Wells forceps and tied with fine catgut, the tourniquet being then removed Additional bleeding points are picked up and tied It is essential to arrest bleeding as completely as possible It is a good thing, after ligature of all possible bleeding points to bathe the wound with sterile

*The limb-makers of today do not object to a moderately tapering stump —Editor

normal saline solution at 120° F to arrest oozing Only absorbable ligatures should be used in an amputation silk or other non absorbable material is very apt to give rise to a sinus at a late stage or it may produce fibrosis with the formation of a painful nodule

Dealing with the nerves—The nerves divided at the amputation must be so dealt with as to avoid painful stump When a nerve is divided the axis-cylinders grow out from the proximal end and if there is no peripheral end into which they can extend they may wander in the tissues adhere and produce a diffuse sensitiveness of a part of the stump If it is possible to confine these new axis-cylinders within the nerve itself a neuroma or end bulb is formed which is not adherent but may for a time be sensitive The formation of such an end bulb is inevitable The aim of the operator should be to make sure that the bulb lies in a protected position is not adherent and particularly is not connected with the surrounding tissue by outgrowing axis-cylinders The best method of treatment of each nerve in an amputation is by (1) pulling the nerve well down crushing it with an appendix clamp or a strong pair of artery forceps (2) ligaturing the nerve with catgut at the point crushed (a large nerve should be transfixed and ligatured) (3) dividing the nerve just below the ligature (Fig 65) By this method the nerve is shortened so that its end lies away from the termination of the stump the axis-cylinders are divided within the sheath by crushing and the ligature tends to keep the neuroma inside the nerve sheath

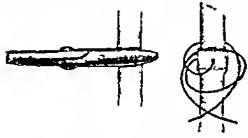

Fig 65 —Method of treating nerve in amputation by crushing and ligaturing at crushed point

Sutures—When the vessels and nerves have been dealt with the wound is ready for suture In most amputations simple interrupted sutures should be used When there is tension on the flap mattress-sutures in which the loop is passed over a small piece of india rubber tube and the knot similarly protected (Fig 66) may be serviceable and permit an amount of tension which would otherwise be harmful

Drainage—It has been the custom to drain all amputation wounds for 24 to 48 hours By this means it was hoped to avoid hæmatoma an important complication because it may lead to the re opening of the whole or a part of the wound and consequent interference with the nature and mobility of the

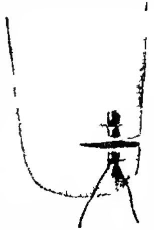

Fig 66 — Mattress suture passed and tied over pieces of india rubber tubing

eventual scar. Experience has shown, however, that drainage does not absolutely prevent the formation of a hæmatoma, and moreover that in many amputations it is not only unnecessary but undesirable from the point of view of the subsequent scar. Each case should therefore be judged individually. If with careful hæmostasis the surface of the wound has been left dry, and there seems no reason to expect much oozing, the wound may be closed completely. Interrupted sutures allow the exit of blood and a hæmatoma is not likely to arise unless some larger vessel begins to bleed. If there is a considerable area of cut muscles drainage is desirable; the tube should then be removed within 48 hours. If a hæmatoma does occur it is generally advisable to re-open the whole wound, clear out the clot and re-suture.

It is desirable to keep the stump at rest for the first week or ten days. This can usually be accomplished by allowing it to lie upon a pillow to which it may be tied. A splint holds the proximal joint in a very rigid position which may be painful, and may cause pressure on the end of the stump. As soon as healing has occurred, movements must be carried out in the proximal joint. A loss of normal range of mobility in the joint above an amputation is a frequent and serious cause of difficulty in the use of an artificial limb. When an artificial limb is not supplied at an early stage, there is a tendency for the patient to keep this joint fixed—for example, to keep the knee or hip flexed; then, when an attempt is made to fit a limb later, the movements of full extension may have become impossible. Movements, and active use of the stump and sometimes massage are therefore required as early as possible.

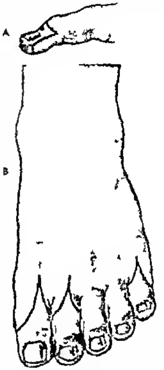

Fig 67.—A, Amputation of terminal phalanx by plantar flap. B, Amputation of toes at metatarso-phalangeal joint.

In the middle three toes the handle of the racket is median. In the big and little toes it is brought well towards the middle of the foot.

Amputations of the Foot

Amputation of the toes.—Amputation of the last phalanx of a toe is frequently required on account of painful corns or painful nails in a deformed toe. It is the most satisfactory operation for recurrent ingrowing toe-nail and for onychogryphosis, and is best carried out by a single plantar flap (Fig 67, A). A transverse dorsal incision is made immediately behind the nail, through a line which marks the level of the interphalangeal joint. The plantar flap includes all the skin on the plantar aspect of the toe, except the extreme tip. The phalanx is then enucleated and the flap sutured in position.

It is not advisable to perform partial amputations of the outer four toes through the first interphalangeal joint, or through the first and

second phalanges The stump remaining is useless and may be a nuisance Amputation through the metatarso-phalangeal joint (Fig 67 B) is often required the best method is by lateral flaps For the great toe the flap taken from the inner side should be the larger and the incision should be carried farther back on the dorsal than on the plantar surface so that the scar lies on the dorsal surface and away from the margin of the foot For the middle three toes the flaps should be equal the incision again being carried farther back on the dorsal than on the plantar surface The incisions should be carried right down to the bone and the base of the first phalanx enucleated with a small bladed scalpel

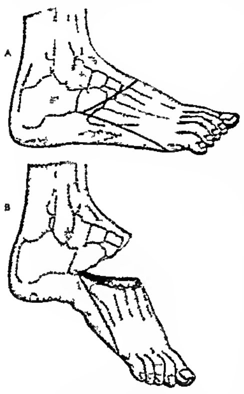

Fig 68 —Lisfranc s amputation.
A Outline of flaps. B Method of disarticulating from dorsal surface.

Amputation of any single toe (including the great toe) leaves the remaining toes as useful parts of the foot Amputation of two toes may leave the remaining toes useful provided that they are mobile and under control But when the second and third toes have to be amputated there is much tendency for the great and fourth and fifth toes to become deformed When three toes have to be amputated it is usually better to sacrifice all The metatarsal heads constitute one of the main bearing points of the foot and should be preserved whenever possible

Amputation at the tarso-metatarsal joints — Lisfranc s operation (Fig 68) is a disarticulation through the tarso-metatarsal joints the ends of the cuboid and cuneiforms being covered by a long plantar flap which extends forwards to the line of the roots of the toes In Hey s modification disarticulation of the second metatarsal bone is not completed but this bone is sawn across Either of these operations requires a very long flap which is seldom available The resultant stumps are good but not easy to fit with an artificial foot These amputations will seldom be indicated

Amputation through the tarsus —Chopart s amputation is a disarticulation of the midtarsal joint covered with a plantar flap cut as far forward as the ball of the toe This amputation requires a long flap so that it is not often possible As ordinarily carried out it has the great disadvantage of leaving the attachments of two strong

tendons—the tendo Achillis and the tibialis posticus—both of them plantar flexors, and the latter an invertor of the foot The peroneal muscles and extensors of the foot lose their attachments, so that the stump, consisting of the astragalus and os calcis, invariably becomes contracted into an equino-varus position, the weight falls upon its antero external aspect, and is painful and difficult to fit with an artificial foot Although the divided tendons can be re-attached in an attempt to prevent this contracture, the stump is never as satisfactory as that of an amputation through the lower end of the tibia and fibula

Subastragaloid amputation is a disarticulation of the foot through the calcaneo astragaloid and astragalo scaphoid joints, the stump being covered by an internal plantar flap This amputation is rarely possible, and leaves a stump which is also less satisfactory than that about to be described

Amputation through the lower end of the tibia and fibula.—The classical amputation at this level is named after Syme, the bones are divided just above the ankle joint and covered with a skin flap taken from the posterior part of the heel When this operation is successful it yields an excellent stump, which is capable of complete end bearing, so that the patient can jump out of bed and walk across his room in the morning without having to put on his artificial foot or use crutches Moreover a cheap stump boot, known as an elephant boot can be fitted, and in this the patient can often walk ten or twelve miles It has, however, certain objectionable features The end of the stump is bulbous, so that it cannot be slipped into a tapering socket but must have made for it a leather socket which fastens with either a lace or a zip fastener Moreover, the stump is so long that it does not leave sufficient clearance to allow the makers to fit an ordinary type of ankle-joint in the artificial foot, and the necessity for the special type of socket and the external ankle-joint subject the end of the stump to friction, with the result that sooner or later it is usually rubbed sore Further, the operation is frequently carried out badly or on unsuitable cases, so that an unsound stump results For these reasons many limb fitters and some surgeons have urged that the operation should be abandoned The advantage that the stump is completely end-bearing and can be walked upon without any appliance is, however, very great, and the modification described below retains this advantage while avoiding the disadvantages

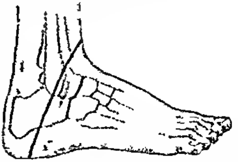
Fig 69—Elliptical incision in modified Syme's operation

Modified Syme's operation—The patient lies on the back, a tourniquet being applied round the thigh and a sand bag placed behind the lower third of the leg The surgeon stands opposite the end of the table An elliptical incision is made (Fig 69), starting

in the case of the right foot, on the outer side of the heel ¾ in in front of the point of the heel It is carried upwards over the tip of the external malleolous across the front of the ankle about 1 in above the joint line, downwards ½ in in front and below the internal malleolus and across the underpart of the heel to meet the commencement of the incision This incision should be carried right down to the bone throughout In the left foot the incision is started on the inner side and carried round in the reverse direction An ordinary strong scalpel or a Syme's foot knife may be used for this initial incision The rest of the operation is best carried out with a short, strong scalpel The ankle-joint is opened from the front the surgeon grasping the foot and forcibly plantar flexing it (Fig 70) The scalpel is inserted between the astragalus and each malleolus in turn, and the lateral ligaments of the ankle are divided by cutting downwards from within out Further plantar flexion of the foot enables the posterior ligaments of the ankle-joint to be divided and the top of the os calcis exposed By carefully cutting close to the bone, the tendo Achillis and the heel pad of fat are stripped from the os calcis which is thus shelled out of its bed Throughout this stage of the operation care must be taken to keep close to the bone and to avoid interference with the posterior tibial artery in the inner part of the flap For the next stage of the operation the surgeon goes to the right hand side of the operating table He divides the periosteum of the surface of the tibia ½ in above the line of the ankle joint and strips the bone upwards until it is clear on all sides The flap being carefully retracted, the tibia and fibula are sawn across one inch above the highest level of the ankle joint The saw-cut must be strictly at right angles to the long axis of the leg Each tendon in turn is drawn down and cut short The anterior tibial and musculo-cutaneous nerves are crushed ligatured and cut short The plantar nerves are dissected from the flap traced up into the posterior tibial nerve well above the level at which the bone is cut, and this nerve is crushed and ligatured The plantar vessels anterior tibial vessels, and long saphenous vein require ligature When all hæmorrhage has been stopped the flap is sutured in position Drainage may be carried out at both inner and outer angles of the wound for two or more days but if the wound is dry it may be left undrained In an uncomplicated case the patient can usually bear weight upon the stump in four weeks

Fig 70 — Syme's operation disarticulation through ankle joint carried out from the dorsal surface

This operation differs from the classical Syme's operation in several particulars —

1 The skin flap is smaller

2 The dissection is carried out from the dorsal instead of from the plantar surface

3 The tibia and fibula are divided at a higher level

The smaller flap and higher division of the bone render the stump much less bulbous than in the classical amputation and leave sufficient clearance to allow the fitting of an ordinary ankle joint The stump should be fitted into a completely enclosing leather bucket which fastens with a zip fastener and is suspended inside a wooden or metal socket of an artificial limb of the ordinary below knee type Friction is thus avoided and the stump remains sound It is however completely end bearing

The amputation can only be carried out when the skin of the heel is intact and unscarred It is sometimes advised that when the outer side of the heel has been damaged an internal flap should be used Practically however unless the operation can be carried out as described the stump will not be so satisfactory as that of an amputation through the middle third of the leg These irregular amputations about the ankle are therefore inadvisable

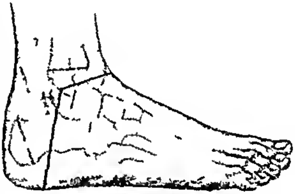

Fig 71—Incision and line of division of os calcis in Pirogoff s amputation

Some surgeons recommend drainage by puncture of the middle of the flap This is very inadvisable as it leaves a scar in the middle of the weight bearing surface

In Pirogoff s operation the tuberosity of the os calcis is kept in the heel flap and made to adhere to the end of the tibia It is in fact an osteoplastic amputation (Fig 71)

In Watson s operation the whole os calcis is retained and shaped so that it fits between the malleoli the articular surface of the ankle joint being removed Neither of these operations presents any advantage over that above described and it is more difficult to fit an artificial foot to the resulting stump

Amputations through the Leg

The stump left by an amputation through the leg carries weight chiefly by a bearing of the lower margin of the patella and head of the tibia upon the upper part of the bucket of the artificial limb The part of the stump below this is only of use as a lever to transmit movement to the artificial limb The leverage thus supplied is better with a large stump than with a short one but there is a limit to the useful length A stump measuring about 7 in from the upper articular

surface of the tibia gives the maximum of utility. A stump which is longer than this requires an unduly thick lower part to the artificial leg, so that it may be impossible to make an ankle symmetrical with that of the normal leg. Apart from this æsthetic reason there is a surgical reason, in that the circulation is defective in stumps left by amputation through the lower third of the leg, the skin over the lower end of the stump often being congested and ulcerating easily. For these reasons, amputations through the lower third of the leg should not be performed. An amputation through the upper third of the leg was formerly called "amputation at the seat of election." The reason for this name was that in an amputation at this level the knee can be flexed at a right angle and a kneeling artificial limb fitted, in which the entire weight is transmitted through the front of the knee. Such artificial limbs are now obsolete, except in cases of ankylosis of the knee-joint, and occasionally in other cases in which for geographical

Fig. 72.—Method of testing ability of a stump below knee by traction upon the flexed knee.

or other reasons it is impossible to fit by better methods. The name "amputation at the seat of election" should, therefore, be abolished. It is possible to utilize the natural knee-joint in the artificial limb even when the stump is very short. The only necessity is that the stump should be long enough to project beyond the thigh at the back when it is flexed to a right angle (Fig. 72). If the knee can be flexed to a right angle and a finger hooked round the back of the projecting stump, it will be possible to fit an artificial limb bucket which will maintain its position as the knee swings. It will be found that a stump containing only 2 in. of tibia, or possibly even less, is thus useful. The best amputation of the leg is through the middle third, preserving $5\frac{1}{2}$ in. of tibia, and above this level all possible length should be preserved up to $1\frac{1}{2}$ in. of tibia. Beyond this point an amputation above the knee will be the correct procedure.

Amputation through the middle third of the leg is best carried out with a single anterior flap (Fig. 73), equal in length to the diameter of the limb, and equal in width to one-half the circumference of the limb at the point of section of the bone. This flap is marked out, with rounded corners, and is reflected with an ordinary large scalpel

A second incision joining the upper extremities of the base of the flap surrounds the back of the limb and divides everything down to the bone The anterior flap being reflected, the muscles and interosseous membrane are divided and the periosteum of the tibia and fibula divided circularly and stripped up for ½ in In sawing through the bone, great care must be taken to divide the fibula at a level at least as high as that of the tibia A projecting fibula is a great nuisance It is a good rule to divide the fibula first, next, holding the saw obliquely, to shave off the sharp anterior angle of the tibia and then to divide the tibia transversely at a level ½ in below that at which the fibula has been cut through The anterior and posterior tibial and peroneal arteries and saphenous veins require ligature The anterior and posterior tibial nerves and the musculo cutaneous nerve should be shortened, ligatured, and divided The flap is then stitched being made to fit snugly over the end of the bone, the wound being drained for twenty-four hours

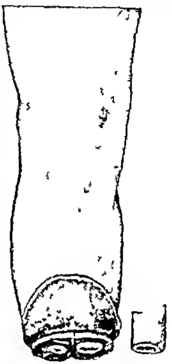

Fig 73 —Amputation through middle third of leg by anterior flap the sharp anterior margin of the tibia is rounded off with a preliminary saw cut

The operation above described closely resembles that recommended by Lister When skin is not available upon the anterior surface of the leg the flap may be almost equally well cut from the posterior surface or from one lateral surface The advantage of the anterior flap is that it leaves no scar over the anterior margin of the tibia It is unnecessary to include muscle in any of these flaps If there is insufficient skin for a single flap without shortening the stump, anterior and posterior or lateral flaps may be used

Other amputations through the middle third of the leg, such as those of Farabeuf, who used a long antero external muscular flap, and Bier, who advocates an osteoplastic method, are now only of historical interest

Amputations through the upper third of the tibia require no additional description, except that the length of the stump is so important that flaps should be cut in whatever way will allow the greatest length of bone to be preserved A hooded flap is useful (Fig 71) An incision is made from the middle line of the front of the leg, curving outwards and slightly downwards around each lateral aspect of the limb in turn, and finishing by passing vertically upwards to a point in the middle line of the calf, about 2 in above the anterior commencing point Lateral flaps are thus left which, when they fall into place, leave a posterior scar In very short amputations there is a tendency for the fibula to

become abducted from the tibia Total removal of the fibula is the best way of preventing this and this procedure has other advantages—(1) that the head of the fibula will not bear pressure in the artificial limb bucket and (2) that its removal will sometimes enable the available skin to cover a slightly longer stump than could otherwise be preserved

In short amputations of the leg the internal and external popliteal nerves should be divided well up in the popliteal space

Disarticulation at the knee-joint—This classical amputation is now seldom indicated It has disadvantages both from the surgeon s and from the limb-fitter s point of view which in the opinion of many entirely contra indicate it If a disarticulation through the knee is to yield a really good stump it must be entirely end bearing and covered with perfectly healthy skin Owing to the size of the condyles of the femur it is seldom that the necessary flaps can be provided in injury cases It has been advocated for gangrene of the foot but in such cases the flaps are likely to slough In malignant disease of the tibia the preservation of large flaps from below the knee may increase the possibility of recurrence These surgical reasons leave very few cases for which the amputation is suitable The objections to the amputation from the limb-fitter s point of view are that the stump is larger at its lower extremity than at a short distance up and that it does not taper The bucket must therefore be made partly at any rate of leather or some similar material laced up in front after the insertion of the stump The knee joint must be provided by external steel joints which are much weaker than a joint that consists of a bolt passing right through the artificial knee When a leather bucket with external steel joints has to be readjusted this entire section of the limb must be remade for if the leather bucket is made to fit more closely upon a shrinking stump simply by lacing it more tightly

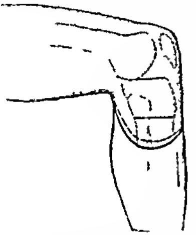

Fig 74 —Amputation through upper end of tibia by lateral mitre shaped flaps

sloping backwards at a level 2 in below the most prominent part of the condyle of the femur, and then passing upwards into the middle of the popliteal space A similar flap is cut on the inner side, and the two flaps, of skin only, are reflected up to the joint level The ligamentum patellæ is divided in its lower part and the upper margin of the tibia exposed The capsule of the joint and lateral ligaments are divided circularly, leaving the semilunar cartilages attached to the tibia The crucial ligaments are cut through, and the whole of the contents of the popliteal space divided directly with a few sweeps of the knife The popliteal vessels and the upper articular and sural branches require ligature The popliteal nerves, long saphenous nerve and internal cutaneous nerve must be shortened The flaps are then stitched into place, and drained for forty eight hours

The classical definition of the point for commencing the flaps as the tubercle of the tibia cannot be retained, for the operation is advocated chiefly for cases in which the tibia is absent In cutting the flaps the important point is to start the incision in front at so low a level that the scar, when it has retracted, will be situated entirely at the back of the stump and will not encroach on the weight-bearing surface A simple anterior flap equal in length to the diameter of the limb at the level of the femoral condyles yields an equally satisfactory stump In Stephen Smith's original operation the semilunar cartilages were left in the stump This is said to be advantageous in that they will help to leave a flatter surface and to pad the end of the stump Actually, they retract backwards to the posterior aspect of the condyles, and are better removed

Amputations through the condyles of the femur.—These amputations need only be mentioned, as they are obsolete In Carden s amputation the bone is divided at the level of the adductor tubercle and covered with an anterior flap containing the patella In the Stokes Gritti amputation the femur is divided at a slightly higher level, the patella is retained its deep surface being sawn off and the remaining part fixed across the end of the femur, again an anterior flap is used The advantages claimed for these amputations are that they are end-bearing and that they retain a great length of femur for use as a lever in moving the artificial limb Actually, the second point is a disadvantage, because the length of the stump interferes with the fitting of a strong type of artificial knee joint The retention of a part of the condyles of the femur makes the stump bulbous at its extremity and necessitates a leather or partially-leather bucket with external steels, as in disarticulation through the knee For these reasons an amputation through the femoral shaft at a level of 2½ in above the articular margin is to be preferred

Amputation through the lower end of the shaft of the femur.—This amputation is to be preferred in cases of injury in which none of the tibia can be preserved, in gangrene of the foot or leg, in malignant

Amputation through the thigh—In amputation through the thigh at a higher level the stump should be kept as long as is consistent with the condition necessitating amputation The ideal length is $10\frac{1}{2}$ inches measured from the tip of the great trochanter The procedure adopted is identical with that in the amputation last described making allowances for differences of level Sufficient portions of the anterior and posterior muscles should be retained to enable them to be sutured over the end of the stump This applies to any amputation up to the middle of the thigh Above this level the extensive attachments of the vastus internus and externus to the bone render retraction less marked and there is no longer any necessity for the retention of muscle in the flap

In amputation through the middle of the femoral shaft there is a tendency to the formation of a spur from the cut end of the linea aspera This spur usually extends backward upward and inward in the attachment of the adductor muscles To prevent this the periosteum should be removed from the femur for ½ in above the level at which the bone is divided and the muscular attachments to the linea aspera separated from the bone for an additional inch

Disarticulation at the hip joint—Disarticulation at the hip-joint may be indicated in injuries involving severe damage to the femur

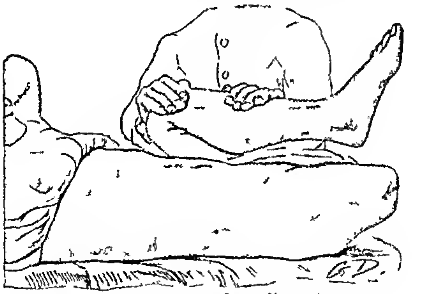

Fig 76 —Thomas's test for flexion of hip joint

By f fl x o of e sound h p he l n b sp n fl ed an l any fl xion on u e he amp ta ie s u p becomes e i n

high up in its shaft in extensive necrosis of the femur in certain cases of tuberculous disease of the hip joint with extensive suppuration and lardaceous disease and in sarcoma of the femur It is an operation which necessarily involves considerable shock and in which owing to the impossibility of using a tourniquet the arrest of

hæmorrhage may be difficult By adopting a method in which the femoral vessels are ligatured early the loss of blood can, however, be reduced to a minimum, and the shock, resulting from the amputation of so large a part and from division of the sciatic nerve, is not necessarily dangerous In fact disarticulation at the hip joint in a patient whose preliminary condition is good is not an operation accompanied with any excessive risk The operation of choice is that in which most of the gluteal and other muscles are removed and a smooth and compact stump is left (Fig 76) Methods which leave a loose, mobile stump make it very difficult to fit a suitable artificial limb

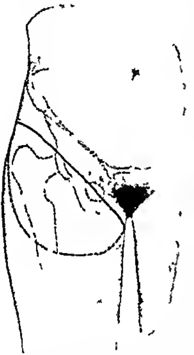

Fig 77 —Amputation through hip joint by posterior flap with preliminary ligature of femoral vessels through anterior incision

The classical amputations are the Furneaux-Jordan method, and amputation by a racket shaped incision with the vertical part in front Neither of these is satisfactory from the point of fitting an artificial limb, because the flap does not fit down sufficiently closely to leave a neat stump without redundant tissue The best method is that advised by Fitz Maurice Kelly, in which the flap is taken from behind and the muscles are removed almost entirely

Amputation at the hip-joint by a posterior flap (Figs 77, 78)—An anterior incision is made through the skin, starting over the adductors just below the inner end of the fold of the groin, and extending upwards and outwards parallel with Poupart s ligament to above the great trochanter This incision is deepened until the common femoral vessels are found, and they are ligatured and divided between the ligatures The anterior crural nerve is at the same time pulled down crushed ligatured and divided A posterior flap is marked out, sufficient in length to cover the stump without tension Its length at the maximum is equal to the antero posterior diameter of the limb at the level of the hip-joint This flap is reflected upwards as a skin flap as far as the tuberosity of the ischium, the sciatic notch, and nearly as far as the crest of the ilium The amputation is then completed from the front all the muscles being divided close up to the pelvis and vessels ligatured as they are met with The great sciatic small sciatic obturator and gluteal nerves are crushed, ligatured and divided close to their exits from the pelvis

In amputations at the hip-joint two methods of dealing with the femur may be adopted either the neck may be divided close up to the head leaving the head in the acetabulum or, when the hip-joint

has been opened from the front the head may be forced out of the socket and the femur removed entirely The former method is only suitable for amputations under aseptic conditions and when the head of the femur is intact it should not be adopted in amputation for sarcoma of the femur Its advantage is that it leaves a rather better surface to the stump Complete disarticulation is necessary in amputation for sarcoma or tuberculous disease of the hip-joint for cases of other infections of the hip and for injuries involving the head of the femur If the head of the femur is left care must be taken that no muscle remains in contact with it for if a muscle becomes adherent to the cut bone it may subsequently disarticulate this from the acetabulum The wound may be sutured with drainage redundant skin being cut away if necessary The remaining stump takes an artificial limb well the weight being borne chiefly by pressure on the tuberosity of the ischium but distributed to a slighter extent over the whole outer surface of the pelvis

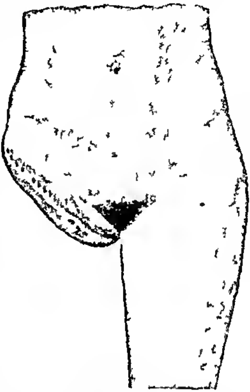

Fig 78 —Amputation through hip joint showing flat stump left when single posterior flap is used

Various methods have been devised for controlling hæmorrhage during disarticulation at the hip joint these include the use of transfixion pins (Wyeth) and of special clamps (the forceps tourniquet of Lynn Thomas) If the amputation is carried out by the above method these special instruments are unnecessary

Furneaux Jordan s operation (modified)—Furneaux Jordan designed his method for cases in which it is necessary to carry out a rapid disarticulation involving as little shock and loss of blood as possible He first used it on a case of chronic osteomyelitis with sinuses and incomplete ankylosis of the hip joint It is suitable for such cases and for old standing tuberculosis of the hip joint but not for cases of sarcoma or for injuries in the region of the head and neck of the femur

Furneaux Jordan first made a longitudinal incision down on to the femur so that he might explore the extent of the disease and decide whether to remove the offending bone excect the hip-joint or amputate He then stripped the femur down to the middle of the thigh dislocated the hip joint and completed the amputation by

division of the skin and soft parts at the middle of the thigh Actually since his time the operation has most often been carried out in the reverse order as described below This method provided that amputation has been decided on in advance facilitates control of the hæmorrhage and it preserves Furneaux Jordan s three principles (1) that the bone should be enucleated where it is most thinly covered (2) that the soft parts should be divided at the middle of the thigh where they are thinnest and (3) that the bulky soft parts at the upper and inner part of the thigh should be left untouched The external iliac vessels are controlled by a tourniquet passed round the perineum and iliac crest and secured by Wyeth s pins or digital pressure may be used (*See* p 482)

A circular incision is made round the thigh at the junction of its upper and middle thirds extending through skin fat and deep fascia These are drawn upwards and the circular incision is carried down to the bone completely round the limb The main vessels and nerves are clamped ligatured and divided A vertical incision is then made down the antero-external aspect of the thigh extending from a point 1½ in above the top of the great trochanter down as far as the circular incision This extends down to the bone which is then rapidly dissected away from all muscular attachments the knife being kept close to the bone which is stripped subperiosteally where possible The hip joint is exposed and the head of the femur disarticulated the entire bone being thus removed During this dissection bleeding points are picked up and ligatured as they are met with bleeding being also controlled by packing and by hot saline solution The wound is sutured with drainage in the usual way

The stump left by this amputation is unsuitable for the fitting of an artificial limb for which re-amputation will be necessary but many patients who have undergone amputation through the hip joint prefer to do without an artificial limb and to depend on crutches

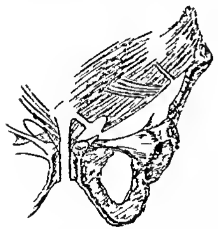

Fig 79 —Interinnomino abdominal amputation Diagram showing division of Poupart s ligament and internal pillar of ring with retraction of spermatic cord giving access to attachment of rectus, which will next be cut through with the symphysis.

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Interinnomino-abdominal amputation —Amputation of the lower limb with the innominate bone has been carried out most often for cases of sarcoma of the pelvic bones or of the femur high up but occasionally also for tuberculous disease and for large innocent growths of the pelvis The method described below may require modification on account of the nature size and position of the new growth * *Spinal in conjunction*

* The surgeon undertaking this operation is advised to consult the account of Hogarth Pringle (*Brit Journ Surg* 1916 iv 283 and G Gordon Taylor *Ibid* 1935 xxii, and 194 xxxvi, 643

with general anæsthesia should be used, and preparations should be made for blood transfusion, the blood being collected in advance and a vein exposed in the antecubital fossa of the arm of the sound side. The transfusion can be commenced either at the outset or as soon as the main vessels are divided, and continued slowly during the operation

The patient is turned partially on to the sound side, with a sandbag against the shoulder and another under the lower part of the thigh of the affected side. When his position has to be altered during the operation the movement should be carried out slowly and carefully,

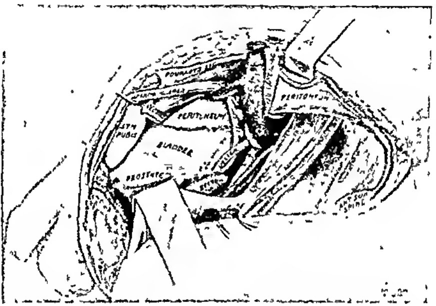

Fig 80.—Interinnomino-abdominal amputation Anatomical structures displayed. The iliac vessels have been ligatured, the symphysis divided and the innominate bone retracted.

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as it is apt to cause an alarming fall of blood-pressure. An incision is carried along the crest of the ilium from behind the posterior superior spine to a point 1½ in below the anterior superior spine, it is continued downwards and inwards, distal to the line of Poupart's ligament, to a point over the adductor brevis 1½ in. below the inner end of that ligament. Poupart's ligament is exposed, the external iliac vessels are ligatured and divided beneath it, and its inner and outer attachments are cut. The inner pillar of the external abdominal ring is divided and the spermatic cord can then be retracted upwards into a safe position The insertion of the rectus abdominis to the pubic bone is divided and, after the bone has been cleared on its superficial and deep aspects, the symphysis pubis is divided with a knife or a saw. If there is a neoplasm which extends on to the anterior aspect of the ilium, it may be advisable to separate the abdominal muscles from

the iliac crest and inspect the peritoneum over the iliac fossa before the external iliac vessels are divided

The patient is then gently turned further on to the sound side A second incision is made, starting at the mid point of the iliac crest, carried vertically downwards as far as the gluteal fold and then following this fold around the inner side of the top of the thigh to meet the extremity of the first incision The gluteal muscles are divided and the dorsum ilii cleared well back towards the sacrum The iliac bone is then sawn through close to the sacrum, this is simpler and more expeditious than disarticulation at the sacro iliac joint If necessary, the small remaining piece of ilium can be detached

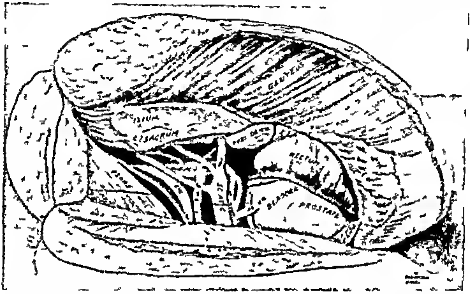

Fig 81 —Interinnominno abdominal amputation The patient has been turned over to the sound side and the dorsum ilii sawn through The nerves and arteries requiring attention are shown, and the line of section of the psoas is indicated

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afterwards If the attachments of the abdominal muscles to the iliac crest have not been divided earlier, this is now done The innominate bone and the lower extremity can now be drawn away from the pelvic peritoneum The lumbo sacral cord, sacral nerves, and obturator nerve are identified injected with novocain and divided The obturator artery gluteal, sciatic and internal pubic arteries are ligatured and divided The psoas muscle is cut through above the pelvic brim care being taken to clear the iliac vessels from it Division of the pyriformis and levator ani and detachment of the ischio-cavernosus and crus penis from the ischio pubic ramus liberate the innominate bone When all bleeding has been controlled, the remains of the gluteal muscles and levator ani are sutured to the abdominal muscles, to cover over the pelvic peritoneum, and the skin is sutured with interrupted stitches No special after treatment is required, except

the necessity to combat shock and to recognize that temporary retention of urine is common

AMPUTATIONS IN THE UPPER LIMB

As already mentioned, the function of an upper limb stump is quite different from that of a stump after amputation of the lower limb The former, particularly in the case of amputations below the elbow, may be useful without any artificial appliance An appliance is really a tool for holding and moving objects The function of the stump is to transmit movement rather than to bear weight Whereas in the lower limb it is often advisable to sacrifice an unnecessary amount of the limb in order to preserve a good weight-bearing stump, in the upper limb the rule that length should be preserved at all costs has very few exceptions Terminal or adherent scars are much less important than in the lower limb In fact, from the artificial limb point of view a terminal scar is the best but lateral flaps with a terminal scar have certain surgical objections—chiefly that such a scar often possesses a poor circulation and tends to ulcerate Any of the methods of cutting flaps may be utilized in the upper limb the circular, elliptical, long and short antero-posterior or lateral and single antero-posterior or lateral methods are all good, practically, the method of cutting flaps should depend upon the skin available As a rule, in the upper limb muscles should be cut at the level of section of the bone and sutured over the bone-ends, for a two fold reason (1) that most of the muscles pass across two joints, and by giving them a new attachment their action on the upper joints can be preserved, and (2) that in the arm, and to a lesser extent in the forearm, there is a considerable tendency for them to retract and leave a conical stump Vessels and nerves should be dealt with as in the lower limb In the arm, sensitive bulbous ends on the nerves are a special difficulty, and it is most important that the nerves should be adequately shortened, crushed, and ligatured

Amputation of the fingers.—Amputation of the fingers or of parts of the fingers is usually required either for injury or for the results of septic infections Much may be written about the advisability of amputating a finger or part of a finger in individual cases Practically, however, in every case the first question is whether the finger, if it is left, even if it is not itself useful, will interfere in any way with the utility of the rest of the hand If it will not, then the finger should, at least for the time being be preserved It may, in fact, be said that amputation of the finger or part of a finger is required (1) when, in cases of injury or sepsis it is dangerous to leave the part in place, (2) when the finger is useless or actually in the way, (3) when it interferes with the use of the rest of the hand

In all doubtful cases the finger should be temporarily preserved, it can always be amputated later There has been some difference of opinion on the retention of any individual phalanx, particularly

the first There need be no such difference of opinion Every part of a finger is useful provided that its joints are mobile Some writers maintain that in amputation proximal to the middle of the second phalanx the attachment of the flexor tendons is lost and unless these tendons are re attached over the end of the stump an immobile stump remains This contention is only true of amputation through the base of the middle phalanx for the flexors of the first phalanx on the metacarpal bone are the interossei and not the long flexor tendons When all three phalanges have to be sacrificed there may be a question whether the metacarpal bone should be left intact or not If the head of the metacarpal is left a stronger hand remains and if a dummy finger is worn in the glove the look of the hand may be quite natural On the other hand the removal of the head of the metacarpal bone allows the fingers to fall together and leaves the absence of one finger rather less noticeable The hand is however not so strong nor can

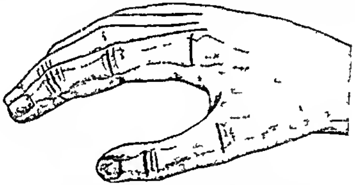

Fig 82 —Level of metacarpo phalangeal and interphalangeal joints in relation to creases of fingers

an artificial finger be worn On the whole when a single finger is amputated it is better to leave the head of the metacarpal if possible

When two or more fingers are amputated the same rule applies The stumps left by the retention of the heads of the metacarpals if they are mobile upon each other form an excellent pad for the opposition of the thumb and even after removal of all four fingers objects can be firmly clasped against this pad by the thumb

It is important for the surgeon to realize the exact level of the interphalangeal and metacarpo phalangeal joints (Fig 82) The classical method of amputation at the terminal phalanx is as follows —

The hand is held palm downwards the surgeon facing the end of the affected finger He grasps the tip of the finger with the left hand flexes the last phalanx to a right angle and with a narrow bladed knife cuts across the finger ¼ in beyond the prominence at the point of bending This cut divides the dorsal half of the circumference of the finger and is carried right into the interphalangeal joint the dorsal and lateral ligaments being divided The joint is further flexed and the phalanx pulled forward The knife can then be turned so that its blade lies parallel with the phalanx and a palmar flap

consisting of the pad of the finger is cut out. When this is of sufficient length, the knife is brought out on the palmar surface. The flap is sutured in position. As a rule, no vessels require ligature. This method is most often indicated in crushes of the dorsal aspect of the last phalanx, and in necrosis resulting from a whitlow.

For amputation through **the middle or first phalanx**, or at the proximal interphalangeal joint, a palmar or dorsal flap, or lateral flaps, may be used. The skin-flap or flaps should first be cut, and the bone divided or the joint disarticulated, digital vessels ligatured and digital nerves shortened as in any other amputation. It is unnecessary to preserve the flexor tendons and suture them to the stump (1) because amputation through the middle phalanx proximal to the point of attachment of the flexor sublimis tendons is undesirable, the *resulting stump being too short* to be useful, and (2) because the first phalanx is flexed by the interossei.

Amputation **at the metacarpo-phalangeal joint** is best carried out through a racket-shaped incision (Fig. 83), the circular part of which passes round the palmar aspect of the finger, level with the lower edge of the web, the vertical incision lying on the dorsal aspect over the middle of the head of the metacarpal bone. Alternatively, lateral flaps may be used, or, if necessary, a flap from either dorsal or palmar surface. It is important to preserve flaps of ample length, or a contraction of the scar may interfere with free abduction of the neighbouring fingers. The flaps having been cut, the extensor tendon is divided over the back of the joint, the joint opened from the dorsal surface, and the phalanx disarticulated, the knife being kept close to the bone. The digital vessels require ligature and the digital nerves should be shortened. Drainage is unnecessary unless the wound is likely to be infected.

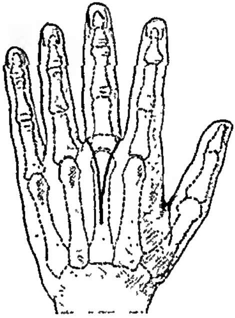

Fig. 83.—Amputation through metacarpo-phalangeal joint by posterior racket-shaped incision.

In the index finger it is better to use lateral flaps, cutting a longer flap from the radial side of the finger, the incision on the ulnar side being carried close to the web between the index and second fingers. This will leave the scar in a more protected position. Similarly, in the little finger a longer flap should be cut from the ulnar side.

Amputation of a finger with the metacarpal bone.—The removal of the finger with a portion of its metacarpal bone is not infrequently

required for injuries which have involved a fracture of the metacarpal with coincident injury of the flexor tendons of the finger If the tendon injury has left a useless finger it may be advisable to amputate but if the fracture of the metacarpal has united in a way which does not interfere with the function of the rest of the hand such an amputation is best carried out through the metacarpo-phalangeal joint When the metacarpal bone is united with angulation or shortening or when non union has resulted the removal of a part of the metacarpal bone is advisable Similarly it may be advisable to amputate a finger with a portion of its metacarpal bone in cases of tuberculous disease or osteo myelitis of the latter bone It is seldom if ever necessary to remove the entire metacarpal bone including its base The function of the hand is much less interfered with if the carpo-metacarpal joint can be left intact In injuries which have involved amputation of the index and middle fingers and in which the metacarpal bones of these fingers have been damaged it is sometimes advisable to remove the greater part of these bones so that there is a wide cleft between the thumb and the ring finger A hand is left which resembles the congenital lobster claw deformity and which proves very useful

Amputation through a metacarpal bone is best carried out through a dorsal incision extending vertically along the length of the bone completed by an elliptical incision carried from the mid point of the dorsal aspect of the head of the metacarpal downwards just below the web of the finger circling the palmar aspect at the lower level of the web and carried back along the same lines on the opposite side of the finger The extensor tendon should be divided at the level at which it is injured or if it is uninjured at the level of the neck of the metacarpal bone This low division of the tendon is advisable because of the linking up of these extensor tendons together on the dorsal aspect of the hand The metacarpal bone is then exposed by a vertical incision through its periosteum the latter is stripped back from the shaft the knife being used only to disarticulate the head and to complete the removal of the base of the first phalanx from the neighbouring tissues The metacarpal is then divided with bone forceps at the selected level and the flexor tendons are cut near the distal extremity of the wound The point of division of the metacarpal bone should be just proximal to a fracture or to any area of disease If sepsis or tuberculous disease renders it inadvisable to preserve the periosteum the amputation should be carried out in the same way but the metacarpal bone should be separated from its surroundings by careful dissection with the knife instead of by stripping the periosteum from it A subperiosteal removal is the better method as it interferes less with the rest of the hand It is particularly indicated for the metacarpal bone of the middle finger because the attachment of the transverse head of the adductor muscle of the thumb is not interfered with If the removal of the entire metacarpal bone is necessary the incision must be carried a little farther towards

the wrist, and the base of the metacarpal carefully disarticulated from its attachments to the carpus and to the neighbouring metacarpal bones In these amputations the digital arteries and nerves are found and divided near the root of the web of the finger Except for veins on the dorsal aspect of the hand, no other vessels should require ligature Drainage is only necessary in cases of sepsis A splint should be applied for the first few days

Amputation of the thumb—Preservation of the thumb, or any portion of it, is even more important than preservation of the fingers Any part of the thumb, even if its remaining joints are stiff, is valuable In fact, partial amputation of the thumb is so rarely called for that the textbook descriptions of set amputations seem almost undesirable When the thumb must be amputated, it will be for injury or disease so severe that a set operation is very unlikely to be practicable Even then, every possible portion should be kept, the stump being covered with skin obtained from any available part, or, if necessary, taken by a pedicle graft from some other area

The terminal phalanx of the thumb is removed in a manner exactly similar to that described for amputation of the same phalanx of a finger At the metacarpo phalangeal joint the best flap is one cut as long as possible from the palmar aspect, with, if necessary, a short posterior flap, this will bring the scar on to the posterior aspect of the stump, where it is least important In amputating through these joints, if possible, the attachments of the abductor pollicis, flexor brevis pollicis and adductores pollicis should be preserved by suturing them over the head of the metacarpal bone to the extensor expansion on the back of the thumb

Amputation of the thumb with the metacarpal bone is very seldom indicated, but when it cannot be avoided every possible portion of the bone should be preserved Formal amputation would be carried out by a racket-shaped incision of which the vertical limb is dorsal, the bone being removed by a close dissection, leaving the muscles as far as possible, but such a formal amputation should seldom, if ever, be required

Amputation through the carpus and metacarpus.—*In injuries* of the hand which necessitate the removal of all the fingers and the thumb, the retention of some of the metacarpal bones, or even of the carpus alone, is worth while if skin is available to cover the stump It is not possible to give instructions for amputation in this region, because in each case the operation must be carried out in such a way as to retain as much as possible of the hand and to utilize all the skin available * It is particularly important to retain the attachments of the flexor and extensor muscles of the carpus to the bases of the metacarpal bones, and if the long flexor and extensor tendons of the

* When there has been much loss of skin from the palm the raw area can sometimes be covered with skin from a finger requiring amputation In these circumstances the phalanges are removed (de bouing) together with the nail bed The resulting skin flap is spread out and turned over to cover the bare area in the palm being fixed by a few points of suture *Even when the digits have escaped injury it may be well worth while sacrificing the little finger for the sake of its skin This is a most valuable expedient in hand injuries.—Editor*

fingers are intact they also may be retained and attached into the bones of the stump These latter tendons should be picked up with Kocher s forceps at an early stage of the operation before they are completely cut through or they may retract into the forearm so that they cannot be reached without reflecting the flap still further A stump in which the wrist joint and the first row of carpal bones are intact will pre sumably be mobile at the wrist and this stump can practically always be used actively by the patient It may in addition be useful to work an artificial hand

Disarticulation at the wrist joint—This amputation is rarely required but is a good one because it leaves the inferior radio ulnar joint intact so that pronation and supination remain The operation is only indicated in severe injuries to the hand necessitating re moval of all the digits and of the carpus and metacarpus and oc casionally in cases of disease (tuberculous or septic) involving the carpus or metacarpus exten sively but leaving the lower end of the radius and ulna undamaged Owing to the size of the lower end of the radius and ulna flaps of a considerable length are required and sufficient skin may not be available in cases which are other wise suitable Although formal amputations are described they are seldom possible owing to this difficulty of securing sufficient skin

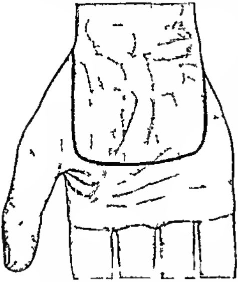

Fig 84 Shape of palmar flap in amputa tion through wrist jo nt

The best method when skin is available is to amputate by a single palmar flap (Fig 84) The incision extends from the outer aspect of the styloid process of the radius obliquely across the base of the thumb as far as the root of the web between it and the index finger then transversely across the palm as far as the middle of the hypothenar eminence and up the ulnar border of the hand to the styloid process of the ulna The skin and subcutaneous tissue are reflected upwards as far as the wrist joint the pisiform bone being included in the flap but the flexor tendons being left behind Any remnants of the thenar and hypothenar muscles should be removed from the flap The posterior incision joins the extremities of the base of the flap across the dorsum of the wrist The wrist joint is opened and disarticulated the entire carpus except the pisiform being removed The styloid processes of the radius and ulna should be cut off with a pair of bone forceps all tendons shortened and the median ulnar and radial nerves ligatured and divided above the level of the wrist joint The

flap is then sutured with drainage. If the palmar skin is damaged, equal antero-posterior flaps or a dorsal flap may be used.

Amputation of the forearm.—Amputation through the forearm is most likely to be required for extensive injuries involving the wrist-joint and hand, and for advanced tuberculous disease of the wrist. As much of the forearm as possible should always be preserved.* Muscles which rise above the elbow joint should, as a rule, be retained and sutured across the ends of the bone. Any flaps available may be used but as a terminal scar is the best, equal antero posterior or lateral flaps with rounded outline are particularly suitable. The skin of the forearm is soft and flexible so that short flaps will suffice.

An amputation with equal antero posterior flaps is carried out as follows. The limb is held out at right angles to the trunk, the forearm being fully supinated. The flaps (semicircular in outline) are marked out and the skin reflected. The muscles are divided circularly, just beyond the level of the base of the flaps. They retract upwards slightly, and the periosteum is then stripped up and the bones cut across at the level of the base of the flaps. The vessels are tied, the median, ulnar, radial, and interosseous nerves ligatured and shortened, the flexor and extensor muscles sutured across the ends of the bone with a few catgut sutures, and the skin sutured with drainage. In an amputation below the middle of the forearm, care should be taken to remove any periosteum which might lie across between the bones, and to fix the stump, until it is completely healed, upon a splint in a supinated position. The object of this is to guard against fusion of the ends of the bones, which would abolish pronation and supination.

Amputation immediately below the elbow-joint.—An amputation which leaves a very short forearm stump has certain objections from the point of view of fitting an artificial limb. When only about 2 in. of ulna remain, flexion of the arm at the elbow brings what was the distal end of the stump into the same line as the anterior surface of the arm, so that the forearm stump practically ceases to exist, and no artificial arm bucket can hold upon it. When the stump is a little longer, i.e. about 3 in. of ulna, a very small hold for the bucket remains, but, owing to the contraction of the muscles attached to the internal and external condyles of the humerus, the antero posterior diameter of this forearm stump increases as the elbow flexes, so that a bucket which fits well in the extended position is too tight when the elbow is flexed. Because of this trouble, no amputation should be carried out which leaves less than 2 in. of ulna. When 3 in. can be left, the amputation is useful in spite of the difficulty in fitting (Fig. 85.) It has been suggested that the forearm muscles should be excised at the time of the amputation or afterwards, but this involves considerable weakening of the stump. It is better, therefore, to carry out this short forearm amputation in the same way as that recommended for amputations lower in the limb.

* Artificial limb makers prefer a stump 6 to 7 in. below the olecranon. (*Ed. for*)

Amputation through the elbow-joint.—There has been some question whether amputation through the elbow-joint is a good operation or not Artificial limb makers dislike it, because it interferes with the strongest type of artificial elbow-joint, but the shape of the stump, which is flat antero-posteriorly with prominent condyles on the inner and outer sides, gives a better hold to the artificial limb and prevents it from rotating on the stump There is another objection, a surgical one, namely, that, owing to the size of the end of the bone, large flaps are necessary and are seldom available From the surgical point of view the amputation is suitable only for extensive injuries of the forearm in which less than 3 in of ulna can be preserved, and for malignant growths involving the lower part of the forearm In malignant growths high up in the forearm, sufficient healthy skin is not likely to be available

Flaps may be cut in any way which the available skin permits (Fig 86) a single posterior flap is as good a method as any To mark

Fig 85 —Amputation through forearm 3 in below elbow by equal lateral flaps with circular division of muscles

out the flap the elbow is flexed to a right angle, the extreme points of the condyles of the humerus are fixed by the fingers of the left hand, and the knife is entered just in front of the point of one condyle and carried downwards with a semicircular sweep across the back of the forearm to a corresponding point in front of the other condyle The length from the tip of the olecranon to the centre of the edge of the flap should be equal to the antero-posterior diameter of the arm opposite the centre of the antecubital fossa The flap should be a little longer on the inner side than on the outer, as the inner part of the lower end of the humerus projects lower down and is larger This flap is dissected up as a skin flap as far as the tip of the olecranon The elbow is then extended and a second incision made joining the extremities of the first and curving down slightly into the middle of the antecubital fossa This anterior incision is carried through all structures into the elbow joint The anterior part of the capsule and the lateral ligaments of the joint are divided, and the forearm removed by dividing the attachment of the triceps The brachial artery and the terminations of the superior and inferior profunda arteries, small anastomotic branches, and superficial veins, require ligature The median, ulnar, and musculo-spiral nerves must be well

shortened crushed and ligatured, and the terminations of the internal cutaneous and musculo-cutaneous nerves should also be sought The wound can then be sutured *with drainage*

If a long anterior flap is used, it will be more convenient to dissect this back first, and then to disarticulate the elbow from the posterior aspect

Amputation through the arm.—Amputation may be carried out through any point in the humerus * If less than 1 in of bone is left beyond the axillary folds, the stump will probably not hold an artificial limb with a mobile shoulder-joint, but a small remaining portion of the humerus should nevertheless be preserved, because this leaves the shoulders more symmetrical When the shoulder-joint is disarticulated, the acromion process forms a sharp prominence which is both

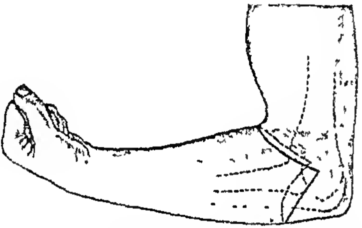

Fig 86 —Anterior and posterior flaps for amputation through elbow-joint

ugly and troublesome Amputation through the arm may be required for injuries or for new growths involving the upper part of the forearm, and for extensive disease of the elbow joint, whether tuberculous or septic

Any flap may be used, but a circular amputation is as good as any Owing to the extensibility of the skin of the arm, very little bone need be sacrificed, as the skin can be pulled down and sutured when the bone has been divided almost at the level of the skin incision The skin and muscles should be divided down to the bone with one circular sweep, the periosteum stripped up for ¾ in , and the bone then sawn across The brachial and profunda arteries and the basilic and cephalic veins require ligature, the median, ulnar, musculo spiral, musculo cutaneous and internal cutaneous nerves require shortening

Disarticulation at the shoulder-joint.—Disarticulation at the shoulder-joint leaves a stump upon which an artificial limb can only be fitted as an ornament Practically, amputation through the shoulder-

* For artificial limbs 8 in below the acromion is the best site (*Editor*)

joint is required only in extensive compound injuries which destroy the head of the humerus but leave available skin capable of covering the stump and in malignant tumours of the humerus

The flaps used to cover a shoulder joint amputation must depend upon the skin available Three classical methods are usually described, in all the incision is a racket shaped one with the vertical limb in front If skin is available in the right part the following modification of Spence s operation appears the simplest (Fig 87) The arm being slightly abducted and rotated outwards a vertical incision is made from the coracoid process in the line of the arm as far as the level of

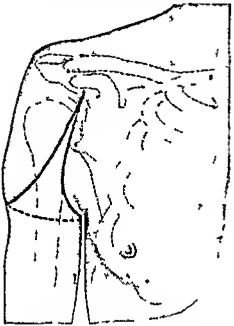

Fig 87 —Amputation through shoulder joint by anterior racket shaped incision.

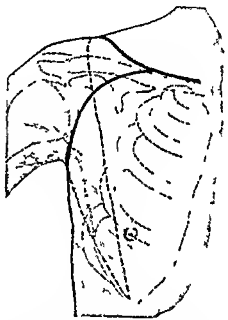

Fig 88 —Lines of incision in cutting flaps for interscapulo thoracic amputation

the anterior axillary fold It then curves outwards across the lower part of the deltoid round the arm at the level of the posterior axillary fold across the axilla and back with a slight curve upwards to join the original vertical incision The antero internal flap is dissected back a short way and the pectoralis major divided The axillary vessels are then found ligatured and divided between ligatures and the main brachial nerves clamped ligatured and cut The postero external flap is dissected back the deltoid being retained in the flap The shoulder joint is opened from the front the long and short heads of the biceps being divided in the process The muscles attached to the tuberosities are cut and also those inserted into the bicipital groove and its posterior margin The humerus is then removed bleeding vessels are ligatured and the flap sutured with drainage Retention of the deltoid leaves a slightly more rounded shoulder than if it is removed

For a malignant growth of the upper end of the humerus it may be adequate to amputate at the shoulder-joint instead of removing the entire upper extremity with the scapula. In this case the same incision may be made, but the flaps should be dissected back superficially, the pectoralis major divided well away from its insertion, and the deltoid removed with the limb. If necessary, the glenoid cavity may be sawn off from the rest of the scapula, so that it and the capsule of the shoulder-joint are removed.

Furneaux-Jordan's method of amputation at the shoulder joint is similar to that of his amputation at the hip joint. The racket-shaped incision is like that described, but extends slightly farther down the arm. The arm is then amputated by a circular method at the level of this incision, and the upper end of the humerus removed by cutting close to the bone. This operation has been recommended for cases of extensive osteomyelitis or necrosis of the humerus. Such cases are now very rare, and it is doubtful whether Furneaux-Jordan's method gives rise to less shock than the method previously described.

Interscapulo-thoracic amputation. (Fig. 88.)—Removal of the whole upper limb with the scapula is usually indicated in malignant disease of the upper end of the humerus involving the shoulder joint or the muscles around it or of the scapula itself. The best method is that of Berger, in which loss of blood is minimized by early ligature of the subclavian vessels. The operation should be carried out as a deliberate dissection, an ordinary large scalpel being used. There should be no hurry, and vessels should all be picked up as they are divided.

The patient should lie near the edge of the table, so that the shoulder overhangs, a sandbag being placed behind the opposite shoulder. An incision is first made along the upper border of the inner two-thirds of the clavicle. Through this incision the clavicle is exposed, its middle third cleared, and the bone cut through, either with a large pair of bone-forceps or with a Gigli's saw. The outer half of the clavicle is pulled forcibly upwards and its under-surface stripped. The outer end is then cut through, the middle portion of the bone being removed. The subclavian vessels and brachial plexus are now exposed, the artery and vein are ligatured in two places opposite the first rib, and divided between the ligatures. It is usual to divide the artery first, raising the arm so as to empty it of venous blood before dividing the vein. An injection of 2 per cent. novocain into the main trunks of the brachial plexus at this stage of the operation will diminish the shock involved in the subsequent division of these nerves. The suprascapular and posterior scapular arteries are now looked for in the posterior triangle and ligatured.

The anterior flap is next completed by carrying the incision from the clavicle opposite the coracoid process downwards and outwards across the anterior axillary fold, obliquely across the axilla down to the inferior angle of the scapula, an assistant manipulating the arm so as to facilitate the cutting of the flap, which is reflected inwards and

for the entire removal of certain muscles when they have become infected with gas gangrene and that infection of the deeper planes is more important than of the skin Œdematous skin may be preserved so long as it is a fairly good colour but an actual infection of a muscle and intermuscular planes beneath the skin indicates amputation at a higher level A tourniquet having been applied the skin is divided by a circular sweep allowed to retract up the limb slightly and a second circular cut made to divide the muscles down to the bone The periosteum is divided and the bone cut through at the same level Vessels are picked up and tied nerves shortened and the wound then dressed with an antiseptic and left entirely unsutured The importance of this method of operating lies in the fact that a flat raw surface is left completely exposed to the action of any antiseptic used and has no pockets in which pus can accumulate

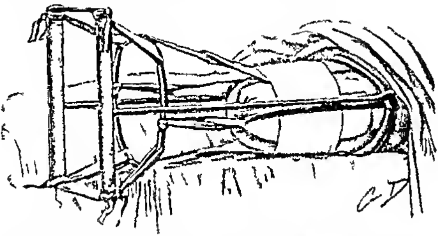

Fig 89 —Method of carrying out skin extension upon modified Thomas s splint

The immediate after treatment of the stump is chiefly designed to subdue the septic infection A good dressing is gauze soaked in a mixture consisting of—

Liquid paraffin	2 000 parts
Flavine	1 part
Methylated spirit	400 parts

This has a powerful antiseptic action and is also comparatively comfortable because it does not adhere to the granulating surface As soon as the temperature has become normal and the wound is covered with healthy granulations a dressing of gauze soaked in plain sterile liquid paraffin may be used instead

If an amputation performed by this method is left to granulate great retraction of the skin and muscles is apt to take place It is therefore necessary to carry out *after treatment* by extension on the skin to diminish the retraction and minimize the subsequent operative measures required A simple method is shown in Fig 89 A splint similar to a Thomas s knee splint with a ring round the top of the thigh

(or the shoulder) but with a square frame at its other end, is applied to the stump Four extension straps are stuck to the skin on different aspects of the stump, either by adhesive strapping or with Sinclair's glue and these are attached to a ring which can then be pulled down and fastened to the frame at the end of the Thomas's splint Extension on the skin is thus made without interfering with the wound at the end which can be dressed without disturbing the splint

(2) An amputation with flaps left unsutured is carried out in the way already described for amputations through the leg or thigh The flap is cut from whichever aspect is desired reflected back as a skin flap, and the rest of the limb then divided at the level of the base of the flap A single flap on one aspect of the limb, or equal or unequal flaps taken from opposite aspects may be used, in accordance with the skin available When the amputation has been completed, the flaps, instead of being sutured, are turned back and an antiseptic dressing applied to the cut surface of the stump, or alternatively the dressing is packed in between them Skin extension will be needed just as in the guillotine amputation except in small amputations such as those of the fingers in fact, the subsequent treatment of amputations done by the two methods is identical

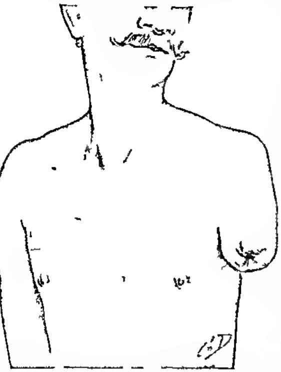

Fig 90 —Stump with terminal puckered scar left by guillotine amputation which has healed without secondary operation In the upper limb such a scar may not be detrimental

When an amputation carried out in the presence of sepsis has been allowed to granulate and is looking healthy its final treatment must depend upon several factors viz (1) the level of amputation and the desirability of shortening the stump (2) the condition of the cut end of the bone, particularly whether there is or is not necrosis, and (3) the amount of skin available to cover in the granulating area If the amputation has been carried out at a site which renders shortening of the stump desirable e g through the middle of the tarsus or the lower third of the leg then as soon as the wound is granulating in a healthy way and the rest of the stump is free from œdema, a complete re ampu tation at the best level immediately above should be carried out (for

example, amputation at Syme's level, or amputation through the middle third of the leg) If the level of the amputation renders it inadvisable to shorten the stump, then, if possible, a secondary suture of the skin over the end of the stump should be carried out The possibility depends on the condition of the bone, if there is necrosis, a ring sequestrum will form and secondary suture cannot be done until this has separated Moreover, the skin available may not be quite sufficient to cover in the end of the stump, and the removal of a small additional portion of bone may be required The removal of this by an incision through the granulating area will almost certainly be dangerous, involving a possible infection of the end of the bone and additional necrosis The procedures then required for dealing with such a stump are, briefly (1) secondary suture when the bone is healthy and the skin sufficient to cover in the stump, (2) secondary suture after an interval sufficient to allow of the separation and removal of any necrosed bone (3) re amputation as soon as possible above the original site when the skin is insufficient to cover over the stump The first can be carried out without delay, the second necessitates a considerable interval, the third may be done as soon as the granulations are healthy and the stump free from œdema, provided that the infection of the bone does not extend upwards as far as the level at which re-amputation is desired The first and second of these procedures requires no special description

RE-AMPUTATION OF A GRANULATING STUMP

Re-amputation of a granulating stump may be carried out (1) when the stump has to be considerably shortened, and (2) when every possible inch of bone has to be retained

(1) When the stump has to be considerably shortened the re-amputation requires no special description, it is only necessary for the surgeon to remember that he has a granulating and probably infected wound at the end of the stump, and to take precautions against infection of the new wound Dusting the area with sulphanilamide has proved most effective, but its action should be controlled bacteriologically The granulating area may be treated, as a preliminary, with a powerful antiseptic, such as pure carbolic acid, and covered up with an adherent dressing (collodion) before the operation begins

(2) When it is necessary to preserve as much as possible of the stump, re-amputation can usually be carried out and aseptic healing secured if precautions are taken as follows The stump is prepared with iodine on the day before operation, as usual At the time of operation the granulating surface and any sinus there may be is swabbed out with pure carbolic acid, the rest of the skin being repainted with iodine The surgeon marks out his flaps, preserving all the skin available, keeping his knife just clear of the granulating area and of the thin ingrowing epithelium, and at the same time removing all superficial scars These flaps are picked up with tissue-forceps and reflected back

as skin flaps With a second knife the muscles are cut through right down to the bone this is sawn across at the required level which must be high enough to preclude any possibility of finding a patch of necrosis During the whole of this part of the operation the surgeon and his assistants must take care never to touch the end of the stump with their hands with an instrument or with a swab In fact, it is better to avoid using any swabs up to the time at which the bone is severed and the end of the stump removed As soon as the bone has been divided the rest of the operation can be carried out as in any aseptic amputation the wound being sutured with drainage for forty eight hours

Fig 91 —Temporary artificial leg for thigh amputation made of plaster of Paris and crutch sticks with webbing harness

The plaster bucket is moulded on the end of the stump with a lining of simple tricot The crutch-sticks are incorporated in the outer layers of plaster bandage. The limb is attached to a waistbelt by a long webbing strap which runs round a roller fixed between the sticks and by a second strap of webbing which is hooked to the outer side of the plaster bucket

AFTER-TREATMENT OF AMPUTATIONS

In order that an artificial limb may be worn with comfort and the stump rendered useful it is necessary to preserve full movement in the remaining joints of the limb and to start the functional use of the stump in an artificial limb as early as possible To avoid the possibility of contracture it is best to fix all stumps on a splint until they are healed As soon as a stump of the lower limb is soundly healed a temporary artificial limb should be applied If an amputation has been carried out through the thigh and the patient allowed to wait for six months before wearing an artificial leg he will spend a large proportion of this time sitting with the

hip joint flexed and abducted, and almost certainly the stump will become contracted into this position, and the fitting of an artificial limb will be seriously interfered with an operation for the correction of the contracture is often required The contracture is most likely to occur in stumps which have healed by granulation and taken a long time to do so This is an important indication for planning out the treatment of a stump so as to secure final healing as early as possible All stumps as soon as they are fit should be treated by daily massage and exercise of the joints In the lower limb the stump should also be kept bandaged from below upwards to promote shrinking before the artificial limb bucket is fitted In the upper limb such bandaging is not required as the shrinkage is less marked A temporary artificial leg can be applied to a lower limb stump immediately the wound is healed The stump will stand considerable pressure at the end of three weeks so that it is possible to fit a limb even on a Syme s amputation at the end of this period Owing to the high cost of an artificial limb bucket, some easily made and cheap appliance should be used for the first temporary limb, e g , the limb made out of crutch sticks and plaster shown in Fig 91 In this the bucket is moulded on the stump out of plaster of Paris, bandaged so that it fits accurately and, as the stump shrinks, a new mould can be made, the limb thus kept comfortable and a uniform pressure exerted upon the stump, shrinkage of which is thus encouraged Such a temporary artificial limb both assists the patient to wear an ordinary artificial leg later and, by bringing the stump into its final condition comparatively early, not only makes it easier to fit an artificial limb-bucket, but avoids the necessity for alteration at frequent intervals afterwards

CHAPTER VII

OPERATIONS ON BONES*

By ERNEST W HEY GROVES

SURGICAL ANATOMY

In modern surgery the accurate recognition of bony points is less important than it used to be because vision by the X rays has to a large extent taken the place of palpation by the fingers On the other hand the scope of operations upon the long bones has made it necessary to be able to expose these structures freely with the least possible damage to the soft structures

Clavicle—This bone is subcutaneous in its entire length and it is easily exposed by an incision which divides nothing but the skin platysma fascia and some cutaneous nerves Total excision for certain new growths or for osteomyelitis is therefore very simple The chief structures which have to be divided in addition to the muscles arising from it are the ligaments attaching it to the acromion and coracoid processes of the scapula and the rhomboid ligament attaching it to the first rib cartilage Commoner problems are those presented by old or recurrent dislocations of the outer or inner end

In dislocation of the head of the clavicle the only common displacement is forward and upward In this the rhomboid ligament and the inter articular fibrocartilage are torn and both these structures are difficult to replace by any form of suture Probably therefore excision of the head of the bone is the simplest treatment especially if the cosmetic effect is the principal aim Dislocation upwards of the outer end of the clavicle involves rupture of the ligaments of the acromio clavicular joint This dislocation is very difficult to retain after reduction and it will be necessary to expose the joint and suture the bones in position with wire sutures Kangaroo tendon may be used but it is apt to stretch and give way before consolidation has taken place.

Humerus—The head of this bone with both tuberosities is so covered by the thick deltoid muscle that no part of it can be clearly defined It lies outside the coracoid process and below the acromion In the intact bone the greater tuberosity faces in the same direction as the lateral (outer) epicondyle and the head has the same relation to the medial (inner) epicondyle The only parts of the bone which are subcutaneous are the two epicondyles The medial (inner) epicondyle is the more prominent and lies just in front of the ulnar nerve

The bone may be exposed for its whole length (but this is very rarely necessary) or for the upper or lower extremities or the shaft

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The whole shaft may be exposed by an incision which lies in the line of the cephalic vein * This line begins at the junction of the outer and middle thirds of the clavicle, above the coracoid process ; it runs down along the anterior border of the deltoid to the insertion of this muscle. (Fig 92A) It then follows down the outer border of the

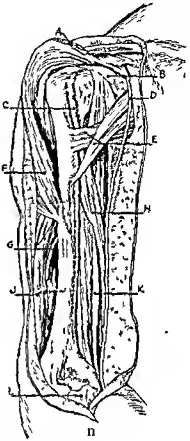


Fig 92A.—Line of incision for exposure of whole length of humerus. (After Henry *British Journal of Surgery*, 1924-5, xii)

Fig. 92B.—After cutting the clavicular origin of the deltoid and turning the muscle outwards (Schematic)

A. Cut edge of deltoid B Coracoid process C Bicipital groove D Cephalic vein E Tendon of pectoralis major *F Insertion of deltoid. G Musculo-spiral nerve J and K Split halves of brachialis* anticus L Coronoid process of ulna. (Henry, *British Journal of Surgery*)

biceps muscle and the inner border of the supinator longus The upper portion of this incision will afford access to the head, neck and upper part of the shaft of the bone The deltoid muscle must be turned outwards for proper exposure of the head. This is done by cutting along the outer third of the clavicle and then raising the clavicular origin of the deltoid with a strip of periosteum or, better still, with the bony margin of the clavicle (Fig. 92B) The deltoid being turned

* Henry *Brit Journ Surg*, 1924 5 xii 84

outwards, the whole anterior aspect of the shoulder joint is laid bare with the head of the humerus enclosed in the capsule the bicipital tendon marking the line between the greater and lesser tuberosities A limited exposure (as required for example in fixing a broken off great tuberosity) may be obtained by splitting the deltoid by an incision which starts at the tip of the acromion but does not go far

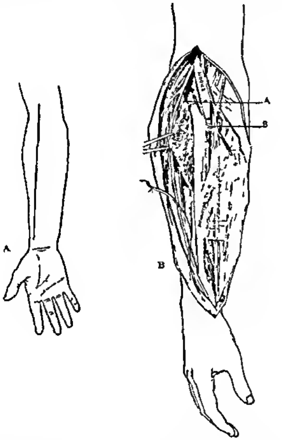


Fig 93—Exposure of the whole radius A Incision for exposure of the radius B The insertion of the supinator brevis has been cut from the radius and retracted.

A Post interosseous nerve B Recurrent vascular loop
(*British Journal of Surgery*)

enough down to damage the circumflex nerve as it crosses the neck of the humerus at the level of the middle of the muscle

The shaft of the humerus is exposed by splitting the brachialis anticus muscle along the line of the above-mentioned incision * This is better than dividing the muscles in the line of the external inter muscular septum because the radial (musculo spiral) nerve will be avoided The lower end of the humerus and the front of the elbow joint are exposed by continuing downwards the splitting of the brachialis anticus muscle to the insertion of its tendon into the coronoid

* Mason *Brit Journ Surg* 1929 x 30

process of the ulna. This anterior exposure of the lower end has the advantage that it is readily combined with the exposure of the shaft, and is therefore useful if dealing with a lesion affecting both parts. On the other hand, it has the drawback of being a deep incision, and the split brachialis muscle is under considerable tension unless the elbow is flexed. A much better method of exposing the lower end of the humerus is that described and illustrated in connection with fractures of the lower end of the humerus. (Fig 118, p. 240.) This is by a posterior incision, through which the triceps tendon and the ulnar nerve are exposed. The former is split into superficial and deep portions and the latter drawn aside This gives a complete view of the lower end of the humerus.

When the wound has to be closed, the overlapping part of the triceps muscle can be brought together in such a way as to lengthen the tendon and so relax tension if required.

Radius.—Only the two extremities of this bone present any surface contact. The head is felt just below and in front of the lateral epicondyle and can be identified by the rotation imparted to it by turning the hand. The styloid process is felt in the floor of the " anatomist's snuff-box," midway between the tendons of the long and short extensors of the thumb.

The surgical exposure of the radius is easy at the head and neck or in the lower two-thirds of the shaft, but difficult in the upper third. The head and neck are exposed by a vertical incision from the tip of the lateral epicondyle downwards. The tendon and muscle over the radial head are those of the common extensors and may, with the radial collateral (external lateral) ligament, be split in the direction of their fibres. This exposes the head of the bone surrounded by the orbicular ligament. The lower two-thirds is readily exposed by a straight incision along the medial border of the brachio-radialis (supinator longus) tendon. (Fig. 93.) The radial artery and nerve are identified and drawn to one side and then the whole shaft from the insertion of the pronator radii teres to the styloid process can be seen.

The exposure of the upper third is difficult because the bone lies so deeply surrounded by muscles, and most of all because the supinator brevis, which lies closest of all, has the posterior interosseous nerve running through its substance, and any injury to this nerve will cause extensor paralysis of the hand and digits. If for some reason the upper third of the bone must be exposed together with the lower two-thirds, then the incision must be along the median border of the brachio-radialis (supinator longus) muscle. (Fig. 93.) It is then essential to dissect out the radial artery and the radial (musculo-spiral) nerve with its deep branch. The former must be retracted medially and the latter laterally. The upper part of the radius is wrapped round by the supinator brevis and this can be divided and turned aside with impunity, always provided the deep radial (posterior interosseous) nerve has been identified and pulled laterally. If only the upper end of the radius has to be laid bare, then it is much safer and easier

to approach it through a posterior incision which runs downwards from the lateral epicondyle to meet the posterior border of the ulna at the junction of its upper and middle third (Fig 94) This exposes the common head of origin of the anconeus and the extensor muscles and this is split in the direction of the fibres or if possible in the interval between the anconeus and the extensor carpi ulnaris This exposes the short supinator muscle, which is turned aside by dividing its origin from the ulna (Fig 95) Both these methods of approach are comparatively difficult, but it is much better to do a

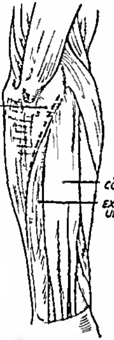


Fig 94 —The back of the forearm, showing the posterior approach to the radius The dotted line is the incision between the anconeus and the extensor carpi ulnaris

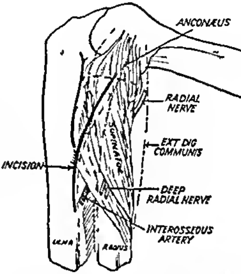


Fig 95 —The back of the forearm after the superficial muscles have been removed (these are shown in dotted lines) The incision separates the origin of the supinator brevis from the ulna.

tedious dissection than to risk the radial (posterior interosseous) paralysis which will result from any blind division of the supinator brevis muscle

The ulna is subcutaneous for its entire length With one exception every part will be exposed by an incision along or adjacent to, this posterior border It is better to avoid any incision over the point of the elbow using rather a curved or U shaped cut above or to the inner side to expose the olecranon The one exception to this posterior approach is the coronoid process, which may be broken or displaced in injuries of the elbow This must be exposed through the anterior incision for the lower end of the humerus

Femur.—The upper end of the femur lies deeply enclosed in muscles, but the great trochanter is almost subcutaneous and gives invaluable

information on the relative positions of the femur and pelvis The head of the femur is almost spherical and its position in Scarpa's triangle may be indicated in the following way Make a triangle by Poupart's ligament above, a perpendicular from the anterior superior iliac spine and a horizontal from the pubic spine A circle inscribed in this triangle will represent the femoral head The tip of the great trochanter lies on a line joining the anterior superior iliac spine and the most prominent part of the ischial tuberosity (Nélaton's line) In drawing this line a common mistake is to be inaccurate in marking the ischial tuberosity This lies below the fold of the buttock If the great trochanter is above Nélaton's line there must be an abnormality of the hip or neck of the femur, either a dislocation of the joint, a fracture of the neck, or a coxa vara Bryant's triangle is formed by dropping a perpendicular from the anterior superior spine (the patient lying on the back) and raising a horizontal line from the tip of the trochanter to meet the former The triangle is completed by a line from the anterior superior spine to the top of the great trochanter The base of the triangle is the line from the perpendicular to the tip of the trochanter The length of this base line as compared with that on the normal side gives a measurement of how much the trochanter is raised in a fracture or dislocation The length of the perpendicular line gives a measurement of internal or external rotation

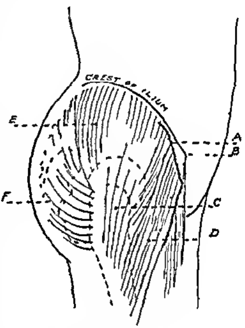


Fig 96—Incision for fractured neck of femur

A Smith Peterson incision
B Anterior superior spine
C Trochanter
D Tensor fasciae femoris
E Gluteus medius
F Gluteus maximus

The length of the lower limb is measured from the most prominent part of the anterior superior spine to the tip of the medial malleolus and is compared with a similar measurement on the other side Unfortunately, this measurement, which may be of great importance, is liable to several errors, particularly in stout or deformed persons

The femur may be exposed in its upper fourth, including the head and neck or its lower three fourths which includes all that part of the bone between the level of the lesser trochanter and the knee joint The upper part can be exposed from one of three aspects, each of which has its special advantages The most generally useful incision

is the anterior or Smith Peterson This runs along the crest of the ilium for its anterior third and then down the line of the sartorius muscle for 4 to 6 inches The tensor fasciæ femoris sartorius and rectus femoris are cut from their pelvic origins the former being turned downwards and laterally and the two latter downwards and medially This exposes the neck of the femur enclosed in the capsule of the hip joint (Fig 96)

The outer incision is goblet shaped, the vertical and curved lines meeting over the tip of the great trochanter The fascia lata is cut in a U shaped flap and the great trochanter exposed Then with a

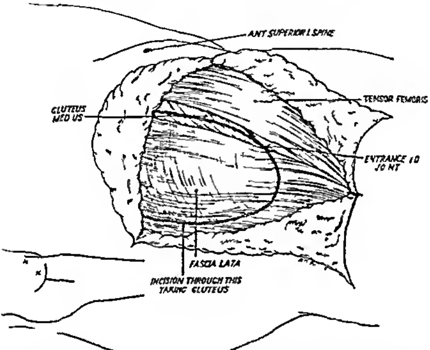


Fig 97 —The exposure of the neck of the femur by the external route Inset the line of incision X X represent the anterior superior iliac spine and the tip of the great trochanter

wire or Adam s saw the trochanter is cut off and turned upwards exposing the neck of the femur and the upper part of the capsule (Figs 97 98)

The posterior incision is made right across the buttock parallel with the fibres of the gluteus maximus and ending below the great trochanter The great gluteal muscle is split and retracted This shows the tendon of the obturator internus with the gemelli and below the quadratus femoris running transversely across the thigh The posterior part of the neck of the femur lies deep to these muscles

Of these three methods of approaching the femoral neck and head the anterior is by far the most generally useful because of the free exposure it gives but it has the drawback that the neck of the bone is approached through the thickest part of the capsule which must

be cut transversely as well as in the length of its fibres before full exposure can be obtained

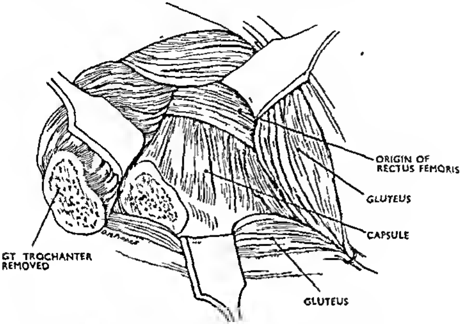


Fig 98 —The exposure of the neck of the femur by the external route. The tip of the great trochanter has been turned upwards

The external incision is only used for certain operations of arthroplasty and arthrodesis, it gives a good view of both the back and the front of the hip-joint, but it is much more severe than the other

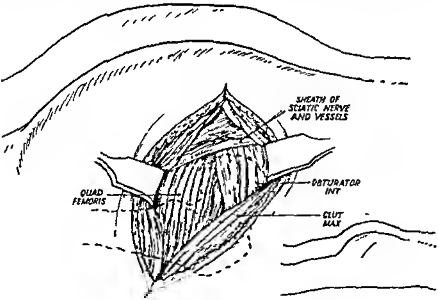


Fig. 99 —Exposure of the neck of the femur from behind Inset shows the line of the skin incision

two methods because of the division of bone and the amount of bleeding

The posterior incision is the easiest and most bloodless and it approaches the hip through the weakest part of the capsule but owing to its depth it only gives a limited view of the parts and the bone is difficult of access for reparative surgery (Fig 99)

The femoral shaft is best exposed through an incision which runs down the front of the thigh on its outer side from the anterior superior spine to the lateral border of the patella This exposes the thigh muscles enclosed in the deep fascia (Fig 100) The latter is divided along the outer border of the rectus femoris and this muscle retracted inwards The deep part of the quadriceps is divided in the line between the crureus and vastus lateralis (externus) taking special care to preserve from damage the nerve to the latter muscle the neurovascular bundle which crosses the upper part of the incision from within downwards and outwards and the supra patellar pouch of the knee joint below (Fig 101)

The popliteal surface of the femur can be exposed either from the medial or the lateral side For the medial exposure a sandbag is placed under the sound buttock and the foot of the affected limb i placed on the opposite shin with as much flexion of the knee as possible An incision 6 in long is made on the inner side of the thigh at the level of the adductor tubercle The anterior border of the sartorius is freed and the muscle is retracted backwards exposing the tendon of the adductor magnus The fascia behind this tendon is then incised and the finger enters a plane of cleavage exposing the popliteal surface of the bone The popliteal vessels lie well behind this plane of cleavage For the lateral exposure an incision is made along the posterior edge of the ileo tibial band two finger breadths in front of the biceps tendon A plane of cleavage is found between the external inter muscular septum and the biceps tendon immediately below the origin of that muscle from the septum By passing the forefinger along this plane the popliteal surface of the femur is exposed The common pero neal nerve lies under cover of the biceps and should not be exposed

The tibia and fibula are practically subcutaneous throughout their entire length At the knee the tubercle of the tibia can be felt in front at the upper end of the crest of the bone The head of the fibula lies behind the lateral tibial tuberosity on the same level as the tibial tubercle The strong biceps tendon can be felt inserted into the fibular head and behind it lies the external popliteal nerve This latter winds round the neck of the fibula and is the only structure which has to be found and preserved when the fibula is cut down upon At the ankle the leg bones present the two prominent malleoli the lateral malleolus lying posterior to the medial and at a lower level

OPERATIONS FOR RECENT FRACTURES

Operations for the direct union of recent fractures are usually matters of expediency rather than of urgency or necessity Th

aim of such operations should be to produce a better functional result than would follow non-operative methods, or to produce it more quickly. It is therefore necessary, in the first place, to be quite sure

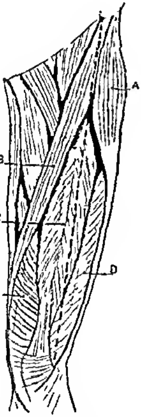


Fig. 100.—Incision for exposure of shaft of femur

A Tensor fasciæ (femoris)
B Sartorius
C Rectus femoris
D, Vastus lateralis (externus)
F Vastus medialis (internus)

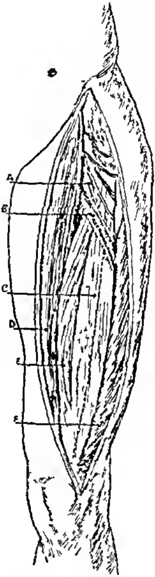


Fig. 101.—The line for division of the quadriceps

A Nerve to vastus lateralis (externus)
B Descending branch of lateral circumflex artery (with veins)
C Crureus. *D* Rectus femoris.
E Vastus medialis (internus)
F. Vastus lateralis (externus)

After Henry Brit Journ Surg 1924 5, xii

which cases of recent fracture require operation, and, in the second, to do the operation in such a way as to produce a good functional result as quickly as possible. To perform an open operation for the

treatment of a fracture involves a very grave responsibility first because properly applied traction and manipulative methods will suffice without operation in most cases and secondly because fracture operations require special skill and experience and in case of failure the patient will be much worse off than if no operation had been performed

Indications —It is difficult to make any dogmatic statement on this subject which would meet with universal acceptance Difference of opinion arises chiefly from two causes—one that the displacement of the bones in a fracture is regarded by some as of little importance and by others as all important the other that those who have had experience of good non-operative methods are much less likely to resort to operation than those who have not The most definite factor in determining the necessity for operation is the persistence of deformity of such a kind and degree as to cause serious loss of function if it is certain that this deformity cannot be corrected by any non operative method

Experience and observation have shown that displacement of fragments in a fracture will cause more or less disability according to the particular bone the region affected the type of displacement and the age and general condition of the patient The circumstances and conditions usually regarded as indications for operative treatment when displacement cannot otherwise be corrected are adult age muscular condition and active occupation of the patient fractures of both bones of the forearm fractures of the shaft of the femur fractures of the neck of the femur separation of the condyles of the femur fractures of the patella and olecranon and fractures of the humerus or tibia in which the displacement is such as to threaten non union

Conditions unfavourable to or contra indicating operation are youth i e any age up to 14 or 15 old age or general feebleness great comminution of the fracture septic infection alcoholism or any serious constitutional disease

Anæsthesia and Hæmostasis

Three modifications of anæsthesia have been applied in fracture operations —

(1) Local anæsthesia —This has the advantage that the period of anæsthesia is longer and the relaxation better than when nitrous oxide is used It also enables reduction to be carried out safely under the screen without risk of explosion It is only likely to be successful however in fresh fractures within the first twenty four hours and is contra indicated in nervous patients and in children

Technique —The skin round the site of fracture is painted with iodine and an intradermal wheal of 1 per-cent novocain over the fracture is raised with a fine hypodermic needle A larger needle is then introduced towards the fracture It is essential to inject the novocain into the hæmatoma at the site of the fracture and blood

from the hæmatoma must be drawn back into the syringe before the injection is made If there are two fractures, they must be anæsthetized separately About 10–20 c c of a 1-per-cent solution of novocain is the usual quantity required After injection, no manipulation should be attempted for five minutes, to allow the novocain to percolate throughout the hæmatoma This is very efficient if the fracture surfaces are separated and if there is a hæmatoma round them into which the solution percolates It is apt to fail if the fracture is impacted and if there is no fluid effusion around it

(2) Brachial plexus block —This is used for the upper limbs Novocain is injected into the nerves above the clavicle, just lateral to the subclavian artery It is uncertain and not free from risk of injury to the great vessels

(3) *Spinal anæsthesia* —This is useful for fractures of the lower limb It gives good muscular relaxation, but involves rather more anxiety for the surgeon and the patient than the usual inhalation anæsthesia

There can be no doubt that prevention of hæmorrhage is one of the most important elements in the technique of all bone operations The muscles and fascial planes of the limb have little or no power to absorb blood effusions, and any extravasation in them is exceedingly likely to lead to infection

A limb to be made bloodless should be elevated to an almost vertical position, and an Esmarch's rubber bandage should then be firmly applied from the distal to the proximal part, well above the area of operation A rubber tourniquet is put on at the upper part of the limb above the Esmarch, which is then removed For an arm it is wise to use the rubber armband of the sphygmograph, and only to apply enough pressure to obliterate the pulse Prolonged excessive tourniquet pressure may cause ischæmic paralysis

If the operation has only involved the division of superficial tissues, the tourniquet should be left in place until the wound has been sutured and firmly bandaged If deep tissues have been opened up, it is wiser to remove the tourniquet before closing the wound, so that all spurting vessels can be caught and tied

Nine operative procedures may be used for recent fractures —

1 *Transfixion by pins or wires*
2 Coaptation with or without impaction of fragments
3 Plating, the plate being fixed by short screws
4 Plating, the plate being fixed by transfixing bolts
5 Cerclage, or fixing by bands or wires
6 Intramedullary pegs
7 Nailing—the fixing of a small fragment to a main bone
8 Suturing by wire or other material
9 Bone-grafting

1 Transfixion by Pins

Indications.—Fractures with marked displacement, comminution, or sepsis, in the femur, tibia and fibula, or (in exceptional cases) the humerus, other conditions requiring powerful traction, such as

certain deformities and dislocations of the hip joint sometimes after arthroplasty to bring about distraction of joint surfaces

Instruments required—Transfixion pins handle for introducing pins, horseshoe grip cord and weight for applying traction splint cradle or sling for supporting the limb during traction

It will be convenient to describe first the operation as done at the *lower end of the femur*

For the mere transfixion gas is usually sufficient 1 per cent novocain may be injected down to the periosteum on the side on which the pin is to be inserted and on the opposite side where the pin is likely to emerge A more lasting form of anæsthesia should be em

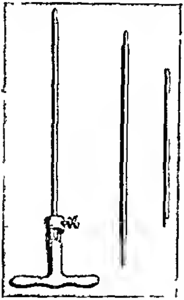


Fig 102 —Transfixion pins and handle

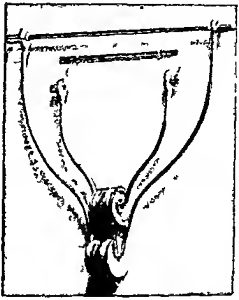


Fig 103 —Metal tractor with pulley wheels

ployed if the transfixion is preliminary to the reduction of a much displaced fracture

Technique—The skin round the knee having been prepared in the usual way is pulled upwards towards the fracture so as to diminish the dragging which may be exerted by the transfixion pin Smearing the skin with a little Bipp* at the point of entrance and emergence of the pin will act both as a lubricant and antiseptic A steel pin 6 in long and $\frac{3}{16}$ in thick shaped like a bradawl at one end and fitted to the handle at the other (Fig 102) is pushed with a boring motion right through the thigh at a point two fingers breadth above the most prominent point of the condyles thus transfixing the lower end of the shaft of the femur the point of the pin should be sharp enough to cut the skin without any special incision A pad of sterile gauze is placed around each end of the transfixion pin and fastened by a bandage The projecting ends are engaged in the corresponding

*For formula see p 769

holes in the horseshoe attachment and the traction cord with the weight is adjusted (Fig 103) As a rule the dressing need not be changed for the few weeks during which traction is continued

When the transfixion-pin has been attached to the femur, the leg is either laid across a pillow, slung to an overhead beam, or arranged on a Thomas's or cradle splint The transfixion-pin can be left in place for about six weeks

Transfixion of the *upper end of the tibia* (Fig 104) is used for applying traction to fractures of the thigh when much sepsis exists or when the fracture involves the lower end of the femur It avoids the risk of adhesions round the suprapatellar pouch which may follow the introduction of a metallic body in close proximity to it, leaving some stiffness of the knee A pin 4 in long and ⅛ in thick is driven through the leg about ¾ in behind and below the tubercle of the tibia Such

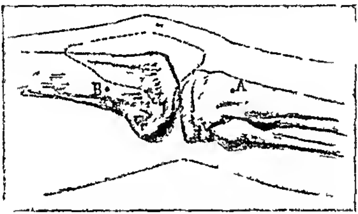


Fig 104 —Points of transfixion of femur (B) and tibia (A)
The dotted line indicates the possible extent of the synovial sac

a pin can be left in place and used for traction for as long as two to three months

The *malleoli* may be transfixed for the treatment of displaced, comminuted, or septic fractures of the tibia and fibula In passing the transfixion pin at this site it should be remembered that the fibula lies in a plane posterior to the tibia and the direction of transfixion should therefore be from within outwards and backwards

The *os calcis* may be transfixed by a ⅛ in steel pin at a point a full finger's breadth below and behind the tip of the external malleolus (Fig 105) This site for a traction pin is used for fracture through the ankle joint or at the lower end of the tibia and fibula

Transfixion is not often required in fractures of the *upper limb* but it may be indicated for fractures of the lower end of the humerus when much displacement or comminution is present The transfixion is made transversely across the olecranon process of the ulna, and the forearm is put up in a position of flexion It is used also for the forearm in cases of exceptional difficulty Wire (not pins) will be

used The distal transfixion is made either through the lower ends of the radius and ulna or through the base of the metacarpus

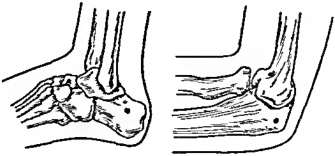


Fig 105 —Transfixion points of os calcis and ulna

The use of multiplying pulleys —The traction which can be applied to the long bones through transfixion pins may be greatly increased by the use of two pairs of multiplying pulleys which are conveniently incorporated in the horseshoe grip attached to the pin and in the upright at the foot of the bed By the use of these pulleys a fourfold multiplication of the weight can be effected and the amount of weight varied according to the number of pulleys used Thus for most purposes a standard weight of 10 lb is employed and this can be made to give a pull of 20 30 or 40 lb according to the number of times the cord is wound round the pulley wheels (Fig 106)

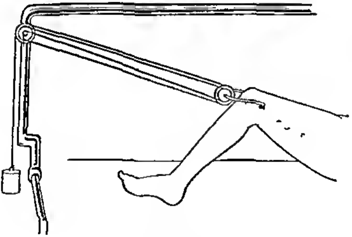


Fig 106 —Multiplying pulleys
(*British Journal of Surgery* 1923, xi 1)

Transfixion pins and plaster of Paris —Another way in which traction through transfixion pins can be used with great precision and effect is by incorporating them in a plaster case This method is most useful in fractures of the leg bones The leg is placed on Bohler s

screw-traction apparatus (Fig 107) A pin is passed through the os calcis and a traction is put on the leg until full length or over-

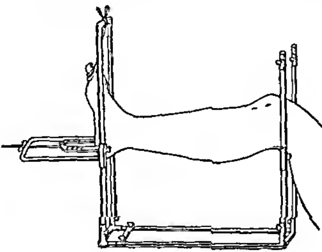


Fig 107.—Leg on Böhler's screw-traction apparatus

length has been attained If the fracture is spiral, then its site of fracture is exposed and, after the bone ends have been accurately adjusted, they are fixed by a transfixion-pin passing through both fragments If the fracture is a transverse one which readily falls into line, then a transfixion-pin is passed through the crest of the tibia just below the tubercle The leg is then encased in plaster of Paris in which the projecting ends of the pins are incorporated After three or four weeks the pins are removed, leaving the plaster case in position for three or four weeks longer (Fig 108)

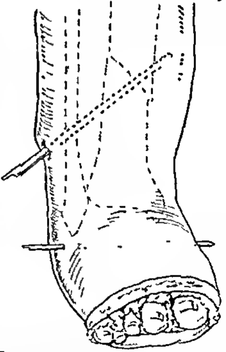


Fig 108 —Spiral fracture which has been reduced by open operation, fixed by one long pin through the fracture and one short pin through the heel Position maintained by plaster case incorporating pins

Transfixion by taut steel wire (*Kirschner's wire*) —In recent years the rigid transfixion-pins have been largely replaced by the use of taut steel wire The advantage is that the fine wire is much less likely to cause damage to the bone or persistent sinus But against this there are two disadvantages first, that if the transfixed bone is at all decalcified, the wire will be dragged through its substance and secondly, that the technique of its application

is more complicated than that of the rigid pins The wire used is 2 mm or less in thickness, made of hardened stainless steel and cut in 20 cm lengths One of these pieces sharpened at the end, is held in a chuck driven by a motor and guided by a collapsible holder, so that it is given the necessary rigidity to act as a drill It easily bores its way through the bone and the soft parts of the limb The projecting ends are now fixed in the ends of a very powerful steel horseshoe which is adjusted by means of a screw winch so as to stretch the wire very tightly The traction is then applied to the horseshoe just as in the pin method (Fig 109)

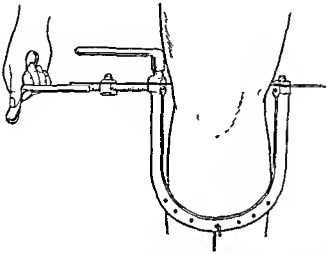


Fig 109 —Lower end of femur transfixed by Kirschner s wire which is here *shown being tightened and fixed in horseshoe stirrup*

The application of traction after transfixion.—In the great majority of cases after the bone has been transfixed, traction is applied by a weight and pulley This acts for a prolonged period varying from three weeks to two months The amount of the weight varies according to the site and the muscularity of the patient, 5 lb for the upper limb, 15 lb for the lower leg and 25 lb for the femur represent the ordinary amounts necessary The principles to be followed are two (1) the weight should be enough to produce a full length and complete distraction within a few days, and (2) it should be gradually reduced when full length has been attained

In exceptional cases traction is applied by means of some mechanical device such as the Hawley table (*see* Fig 34, p 120) or by a screw-traction apparatus of which there are many on the market In this method the pull is by a screw, and any amount of force, op to 200 lb, may be used, but this should be measured by a spring gauge and applied slowly It is chiefly used as a preliminary to double transfixion and encasing the limb in plaster, e g in fractures of the os calcis, or lower leg bones This method has the advantage that it can be

done under the X-ray screen and that accurate anatomical reduction can often be obtained in a few minutes

2 Coaptation With or Without Impaction of Fragments

In many cases an open operation for fractures does not require the use of any fixation appliance It is only necessary to expose the fragments, to remove intervening soft parts and then to lock the broken ends by fitting them together Such an operation is most typically seen in the fracture at the junction of the shaft with the expanded end of the bone, e g at the surgical neck of the humerus or in the bones of the forearm, especially the radius (Fig 110)

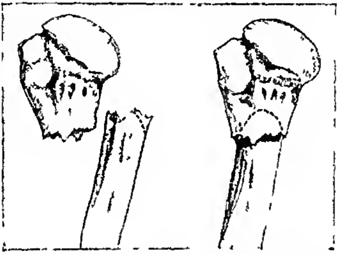


Fig 110 —Fracture of humerus treated by impaction

Instruments required.—Scalpel, two pairs of dissecting forceps, scissors, retractors, bone levers several periosteal elevators, two pairs of bone-holding forceps, sequestrum forceps, bone-cutting forceps, blunt dissector, chisel, gouge and hammer, small saw, file, twelve pairs of pressure forceps Michel's clips and clip holding forceps fine ligature catgut, silkworm gut, curved cutting needles, stockinet, Horsley's wax

To avoid repetition, this set of instruments will be referred to in descriptions of later operations as the "bone set"

Technique.—The limb, having been sterilized, is covered by a layer of stockinet, through which the incision is made The edges of the latter are clipped to the stockinet by means of Michel's clips The incision need only be of such a length as to allow the fractured ends of the bone to be caught by forceps and drawn into the wound Before doing this, if a tourniquet has not been used, all bleeding-points are caught and ligatured, the muscles covering the bones are fully retracted, and bloodclot is removed The fragments, having each been firmly grasped by forceps, are brought into the wound so that the long axis of each is angulated in respect to the other If the fracture is approximately transverse and the fractured surface consists of well-marked jagged spikes, it may be possible to fit the two ends together

in such a way that the muscle tension alone will be sufficient to keep the fracture in good apposition But in many cases this is not possible, either the fitting cannot be made, or the projecting spikes are not well enough marked to secure interlocking In these circumstances the shaft may be pointed, advantage being taken of any natural spike, or it may be formed into a cone by sawing, chiselling, or filing The surface of the expanded articular end is slightly hollowed out by a gouge, and the pointed end of the shaft is then forcibly driven up into it The soft tissues are sewn together round the fracture by deep catgut stitches, so as to obliterate dead spaces and also further to fix the fracture The skin having been closed by interrupted silk-worm-gut sutures and a dressing applied, the limb is put up in such a position that traction on the seat of fracture will be avoided For example, in fracture of the neck of the humerus the arm should be put up in full abduction by an abduction splint or a plaster of Paris case

3 Plating with Short Screws

This operation, introduced and perfected by Arbuthnot Lane, was at one time a routine method It has now, however, been given up by most surgeons It ought to be reserved for special cases It is particularly indicated in fractures of the shafts of the long bones, where extensive exposure is possible and, in addition to two main fragments, an intermediate wedge-shaped piece is broken out Plating is unnecessary for simpler types of fracture, and it is inefficient for cases of delayed union and non-union The exposure of the bone ends stripping of periosteum, the drilling of the bone and leaving massive foreign bodies in the tissues, all tend to devitalize the bone and so greatly delay natural callus healing

Instruments required.—In addition to the bone-set (p 233) plates and screws of a suitable size plate benders, drills for boring holes in the bone, screw-driver, screw holding forceps, plate-clips, and distraction device

Technique.—In fractures of the large bones, such as the femur or tibia, it will greatly facilitate the plating operation if preliminary traction has been made on the broken bone for about 3 to 6 days, *so as to bring it to the full length required* In this, as in all bone operations where foreign material is buried in the tissues, special precautions should be taken to avoid septic infection In addition to a scrupulously careful technique, it is well to wear cotton gloves over rubber ones, in case the latter tear Many surgeons, however, adopt a special ritual, never touching the tissues even with the gloved hand, avoiding contact with any swab or ligature which goes into the wound, and not handling the " business end " of any instrument The limb is protected by stockinet A long incision is made, if the bone is subcutaneous, like the ulna or tibia, the incision should be curved so that neither wound nor scar may lie over the fracture In order to obtain firm hold on the bone and to act as an efficient internal splint, the plate ought to be from one-third to one half the

length of the injured bone. For the insertion of such a plate the incision will have to be still longer, i.e. it is usually about three-quarters of the length of the bone to be mended. The edges of the stockinet are clipped to the wound either by Michel's clips or by long-handled tissue-forceps, which will then also serve as retractors. The fascia is cut through, and the muscles are separated or divided until the shaft is reached. Great care must be taken that nerve-trunks, such as the radial (musculo-spiral) over the humerus or the posterior interosseous round the radius, are not injured. All bleeding-points should be secured by fine catgut ligatures, and loose bloodclot removed. The soft tissues having been retracted, the periosteum is divided along the surface of each fragment, so that soft parts, together with the periosteum, can be peeled off the bone. When this has been done, retractors should be placed in the wound in such a way as to press aside the muscles and also to protect them from injury. Fagge's pattern of retractor (Fig. 111) is one with a curved point which

Fig. 111.—Fagge's model of Lane's lever-raspatory.

underlies the bone and a flat shank which protects the muscle, and is very convenient.

The bone having been exposed for a length amply sufficient to allow easy application of the plate, the next and most difficult stage of the operation consists in manipulating the fragments so that they fit one another exactly. The whole reason and justification of the operation will be sacrificed if the plate is applied to the fracture while the fragments remain awry. The plate is not intended to be a permanent union between the bones; it is only an internal splint to hold the bones together while natural union occurs, and the main reason for using such an internal splint, instead of an external one, is that the fragments can be correctly replaced. The great difficulty in effecting restitution is tension and contraction of the muscles and soft parts. Great overlapping should have been treated by preliminary extension; in addition, it is always wise, in large bones like the femur or tibia, to make provision for strong traction to the limb during operation. This is best provided by the use of Hawley's table (Fig. 84, p. 120) or the portable traction set which can be placed on any table. There are many more modern "orthopædic" tables than Hawley's, but all are mere elaborations of it, and most of them are over-elaborate. It consists essentially in a pelvic rest and a vertical bar which lies between the legs. Traction, abduction and rotation are provided for by a screw apparatus carried on two long steel bars.

When once the tension has been overcome, there will be little difficulty in making lateral, axial, or rotatory adjustment. Each of

the main fragments is grasped by a suitable bone holding forceps and these are used as a handle for manipulating the bones and for holding them in position until the plate is firmly fixed in its place These bone-forceps are made in various patterns Lane s (Fig 112) have very long handles and are powerful but have no adjustment for

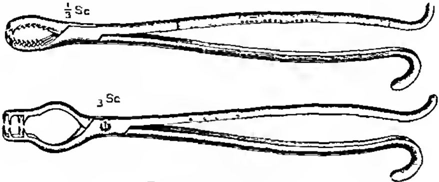


Fig 112 Lane s forceps

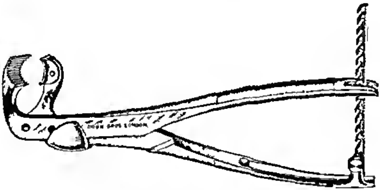


Fig 113 —Lambotte s forceps

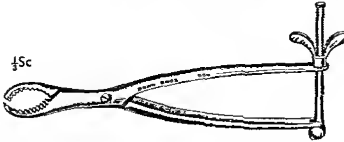


Fig 114 —Hey Groves s forceps

locking them in position, Lambotte s (Fig 113) have the handles at right angles to the blade with swivelled jaws and a ratchet catch which locks the handle Hey Groves s (Fig 114) are straight and have a screw lock Lowman s pattern is like a sliding clamp which has the advantage of clamping the plate to the bone but requires that the bone should be freed more extensively than is necessary with other forceps and also it is more difficult to adjust

The main fragments having been seized by the forceps, the final adjustment is made by slightly angulating the two fragments into the wound, making them interlock, and then straightening the bone Adjustment may sometimes be assisted by suitable levers (Fig 116) This applies to a transverse fracture If the fracture is oblique, it will be convenient, after adjustment, to fix it by a third pair of forceps which grasps both fragments If there is a third, small, intermediate fragment, then one of two methods may be adopted, according to

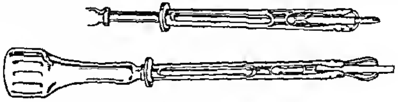


Fig 115 —Sherman screwdriver

circumstances The small fragment may be adjusted to one of the large fragments and there fixed by the plate, the other large fragment is then brought into position and fixed to the projecting end of the plate Or the two main fragments are brought into position, and there held by a bridging plate clamped in the forceps while the third fragment is fitted into position

When the fracture has been adjusted and the plate placed in position, a series of holes is drilled into the bone by a mechanical

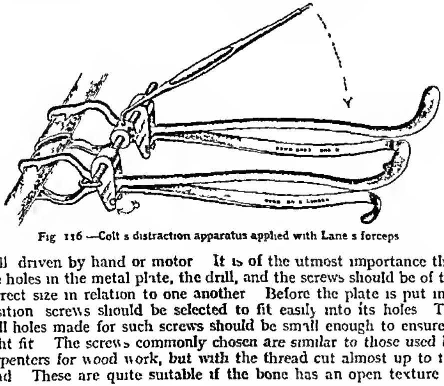


Fig 116 —Colt s distraction apparatus applied with Lane s forceps

drill driven by hand or motor It is of the utmost importance that the holes in the metal plate, the drill, and the screws should be of the correct size in relation to one another Before the plate is put into position screws should be selected to fit easily into its holes The drill holes made for such screws should be small enough to ensure a tight fit The screws commonly chosen are similar to those used by carpenters for wood work, but with the thread cut almost up to the head These are quite suitable if the bone has an open texture in

which the screw thread easily buries itself For hard dense bone such as the femur or tibia it is better to use Sherman s screws the thread of which is like that of an engineer s screw used for metal work (Fig 115) These screws have slots at the sides of the point by which a thread is cut to receive the shank of the screw The screws are driven into position as firmly as possible without overturning the screw so as to avoid stripping the thread cut by it in the bone The carpenter s screw is held by special forceps (Lane s) while being driven in by a screwdriver the Sherman s screw is fixed in a special screw driver which holds and drives it at the same time The actual number of screws used will vary with the length of the plate but while it may not be necessary to place a screw in every hole it is wise to use at least three screws for each main fragment If the main fragments are securely fixed it will not be necessary to drive many screws into the third fragment and frequently the latter can be adjusted *without any screw at all* Small fragments can often be safely and securely fixed by strong chromic catgut passed around the bone

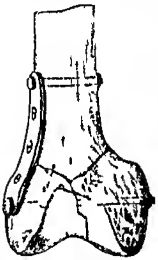


Fig 117 Bent plate bolted to lower end of femur

When the femur is being plated in the curved part of the shaft the plate should be suitably bent by special bending levers so as to fit the natural curve of the bone (Fig 117) Special steps should be taken to prevent the ends of the plate becoming separated from the bone by the powerful leverage of the femur at a time when the bite of the screws in the bone has become loosened There is always a tendency for the shaft of the femur to become angulated outwards because of the predominant action of the adductor muscles This will separate the plate from the bone at one end or the other and even if firm union occurs there will be some deformity

The plate being firmly fixed in position the forceps are removed *and the soft parts brought together in layers so as to cover in the* plate and screws as snugly as possible The ideal aimed at should be to bury the plate between the bone and periosteum so that it becomes embedded in the layer of external callus The muscles and deep fascia are brought together by a few interrupted catgut stitches and the skin is united by clips or silkworm gut If there has been much oozing a few strands of silkworm gut or a rubber strip may be used as a drain which should be removed within twenty four hours The dressing having been applied the limb should be put up in a splint which securely protects the bone from external injury or distortion by muscular tension

In the femur a Thomas s splint is most convenient as the leg can be slung up from the bed and the dressing can be changed without

taking off the splint If there is much oozing, the dressing is changed the day after the operation, and again on the tenth day, when the wound is dressed, all stitches are removed and the limb is suitably encased in plaster of Paris This will avoid the danger of displacement of the plate and screws by muscle strain At the end of two to three months the limb can be used, but some kind of case splint—or, in the case of the femur, a walking calliper—must be worn for some time longer During recovery, and as soon as possible after the operation, the principal joints should be moved, whilst massage or electrical treatment is applied to the muscles, to prevent stiffness and wasting

This description of a plating operation applies more particularly to the *femur*, and as it is in general terms it will be necessary to add a few words on special conditions relating to particular bones It is doubtful whether it is ever necessary or justifiable to plate a fracture of the *clavicle*

The *humerus* presents many difficulties for plating, and is generally much more amenable to other operative methods of repair This bone is so closely surrounded by important vessels and nerves that it is very difficult to make a free exposure of its surface long enough for the application of a plate The upper third of the shaft should be exposed by a vertical incision down the middle of the front of the arm, which opens the soft tissues between the deltoid and pectoralis muscles If necessary, the tendon of the latter may be cut through and sutured at the close of the operation There will always be a difficulty in obtaining sufficient exposure of the upper fragment, and the substance of this part of the bone is too soft to afford a good screw-hold

The middle third of the humerus should be exposed by an incision running along the outer border of the arm from the insertion of the deltoid muscle down to the external condyle The radial (musculo-spiral) nerve should be sought for and carefully retracted by a strip of gauze

There are certain fractures at the lower end of the bone which may require operation, of these the most typical is a Y-shaped fracture into the elbow-joint with separation of the condyles As the main object of the operation is to make an exact restitution of the joint surface, it will be necessary to provide a free exposure of the elbow. This is best done by a longitudinal incision over the back of the joint, curved so that the scar shall not be over the tip of the olecranon The tendon of the triceps is exposed and is divided longitudinally into a superficial and deep portion, the former being left attached to the olecranon, the latter to the shaft of the humerus These two parts of the triceps are turned downwards and upwards respectively, the ulnar nerve is identified and held aside, and the lower end with the articular surface of the humerus is thus fully exposed (Fig 118)

Although it is then possible to fit on a Y-shaped plate, it is usually

much better to be content with fixing the broken fragments by fine wire nails or by kangaroo tendon, because these produce much less reactive fibrosis in the joint

The arm is placed in a position of moderate flexion of the elbow, and the overlapping parts of the triceps are sutured without tension, using stout (No 3) chromicized catgut

Plating of the *forearm bones* is done for fractures of both bones, or for that of the radius alone with much displacement It is doubtful if fractures of the ulna alone ever require operation The two bones

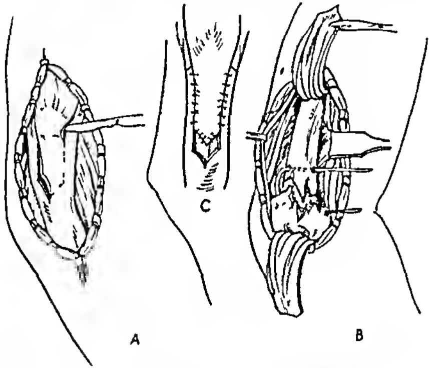


Fig 118 —Method of exposure of a fracture of the lower end of the humerus
A Method of dividing triceps B Exposure of fracture obtained by this method C. Suture of triceps to lengthen tendon.

should be exposed by separate longitudinal incisions, that for the ulna being along its posterior subcutaneous border, while that for the radius should be along the inner margin of the supinator longus muscle Plates about 4 in long should be used and, while that applied to the ulna is straight that applied to the radius should be suitably bent if it is to be fixed to the curved part of the bone It is easier to deal with the radius first, taking great care to secure correct position of the fragments in respect of rotation Usually, the upper fragment is fully supinated by the action of the biceps, and the lower fragment must be adapted to this In fractures of both bones it will often be enough to operate on the radius, leaving the ulnar fragments to find their own adjustment

In plating the *tibia* the incision should be curved outwards so that

it will not lie immediately over the broken bone The plate should be applied to the lateral surface of the bone, that is, behind the crest, where the bone is covered by the muscles between the tibia and fibula

Plating of the femur should be done through a long external incision between the rectus femoris and the vastus externus

Removal of plates.—When plating operations were introduced, it was never contemplated that the plates and screws should be removed, but now removal has been suggested After a successful plating operation the metal bodies become buried in new bone and cause no pain or other symptom In these circumstances it is foolish to interfere with them Plates and screws should never be removed unless they cause inflammatory reaction shown by osteitis pain or a sinus

Plating tends to delay natural repair by callus If a plate is removed after two or three months, the weak callus repair may give way and non union result

Complications after plating.—Not infrequently after plating operations a sinus forms in a part of the wound or at one of the stitch-holes Very often it will heal spontaneously, and there need be no hurry in opening the wound or removing the plate The short screws used to fix the plate may become loose at any time after operation, but most frequently after a considerable period, months or even years The formation of a sinus and the loosening of the plate are the subjects of much difference of opinion On the one hand, it is held that they are really due to primary infection of the wound and can only be avoided by special aseptic precautions during the operation On the other hand, there is convincing evidence that both are due to defective mechanical fixation A third view is that the metallic foreign body irritates the living tissues, causing absorption of bone, loosening of screws, and the formation of a sinus Two facts may here be mentioned, both of which are borne out by experimental and clinical evidence One is that the formation of the sinus takes place some time after the operation and when the incision has healed without trouble, which would indicate that it is due to a disturbance from within and not to an infection from without The other is that large plates may be securely fixed by screws or bolts without any irritation or the formation of a sinus it is the small plate, or the plate insecurely fixed, which is usually associated with these complications

The practical difficulty is to decide what to do when a sinus arises or the plate becomes loose In the early stages, the limb should be fixed by a good external splint—the best usually being a plaster case—in which a window is cut If this produces good union, with healing of the sinus, nothing further will be necessary But if the sinus persists, or if the X-rays show that the plate and screws have come adrift when union ought to have taken place, then they had better be removed On the other hand, there is no justification for removing the plate and screws simply to get rid of the foreign material if smooth healing has taken place There are some cases in which, long after

union, pain is complained of at the seat of fracture Such cases usually show a pronounced thickening of the bone in which the plate lies embedded It is possible that such a thickening may be partly inflammatory and the plate and screws are commonly removed This does no harm, and free exposure of the bone and removal of the plate and screws may give relief On the other hand, in most cases of successful plating, both plate and screws remain in position for an indefinite period without causing symptoms

4 Plating with Bolts

Plating performed in the ordinary way with short screws has certain drawbacks and limitations, the chief of which are the tendency of the screws to be pulled out by any force which tends to angulate the bone, and the consequent liability of the bone to displacement before union Usually this drawback to plating may be overcome by the addition of clips to the two ends of the plate, or by careful external splinting There are, however, certain conditions in which the plate should be fixed to the bone by bolts that traverse its whole thickness The best example is where a fracture of the *lower end of the shaft of the femur* is associated with separation of one or both condyles

Instruments required—The bone set (p 233), drills of sufficient length to go right through the bone, plates and plate benders, screws and screw drivers, bolts, nuts and washers, spanners fitting the nuts, strong wire cutters

The bolts are made 4 in long and $\frac{1}{4}$ or $\frac{5}{32}$ in in thickness, with the head cut for a screw-driver and a nut with an hexagonal or a milled head They are made of soft steel so that they can be cut to any length by strong wire-cutters Each bolt must be provided with two washers of at least $\frac{3}{8}$ in diameter, one of which at each end prevents the head of the bolt or the nut from sinking into the bone

Technique.—The site of fracture must be exposed by two lateral incisions, one long and one short, the former to allow the plate to be placed, and the latter to adjust the nuts on the other side of the bones The first part of the operation, the exposure of the site of fracture, is exactly similar to that already described A plate of suitable size is now taken and bent so as to fit the natural contour of the bone A bolt is passed right through both condyles and through the lowest hole in the plate, and fixed by the nut and washer (Fig 117) A second bolt is used for the upper part of the plate to fix it against the shaft of the bone, and, if thought necessary, one or two short screws may be added This method of fixation will give such a secure result that movements of the knee can be undertaken as early as three to four weeks after the operation The limb should be put up on a splint with the knee partly flexed

5 Cerclage or Fixing by Bands or Wires

The use of wire in the fixation of fractures has been somewhat hastily abandoned by many surgeons because, in the early efforts at bone fixation, it was customary to tie bones loosely together by thin wire,

and the result was so bad as to justify the adoption of some other method It is not the use of a metallic substance buried in the tissues which leads to the formation of a sinus or to non union it is the insecure fixation of the fragment, which permits the movements of bones on one another, and causes irritation that leads to the wound breaking down If the fracture is suitable for wiring and if the wire is of the right size and kind and is properly applied and fixed, this operation is perfectly satisfactory

The *indications* are very well defined a long oblique or spiral fracture which cannot be satisfactorily reduced by traction methods The obliquity of the fracture should be such that the length of the broken surface is more than twice the breadth of the bone

Instruments required.—In addition to the bone set (p 233) Parham's steel bands and fixing instrument or iron wire wire tightener and wire cutters, and curved wire-introducers of different shapes and sizes

Technique.—The exposure and reduction of the fracture are carried out on exactly the same lines as described for plating The fracture is

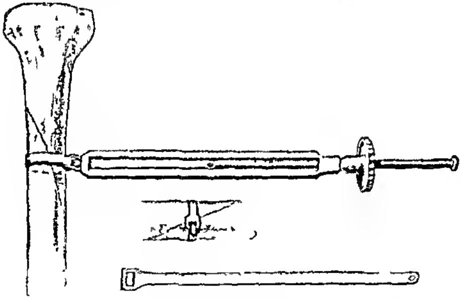


Fig 119 —Parham s band

fixed in position by a bone clamp forceps, which is placed about midway between the ends of the fractured surfaces A band or wire loop is then passed round the bone, as near to each end of the fracture as will secure a firm grip of the sharp ends Parham s band (Fig 119) consists of a flat band of soft steel, $\frac{1}{16}$ in wide and $\frac{1}{50}$ in thick One end of the band is expanded and perforated by a slot large enough to take the other portion of the band The opposite end has a hole which is caught by the tightening instrument The band having been passed round the bone, the small end is threaded through the slot in the large end and the loop so formed is drawn as tight as possible The project-

ing end is then fixed in the screw-tightening instrument and the band pulled quite taut, after which it is bent sharply down, removed from the tightener, and cut off so as to leave a sufficient length for fastening If wire is used, it should be unannealed iron wire of a gauge of 16 14 or 12 This wire is much stronger than silver and, being quite cheap can be used in long lengths so that it can be tightened more efficiently than short lengths merely tightened by twisting A method of tightening the wire is shown in Fig 120, using a double loop Whether a band or a wire is used, it is essential for success (1) that the fracture be firmly and accurately fixed by the forceps before the metal circles are put in position (2) that the metal sutures be strong enough to hold the bone, and (3) that they be drawn absolutely tight and firmly secured before

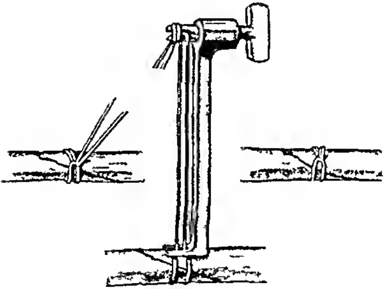


Fig 120 —Wire tightened by special instrument

the release of the forceps If the fracture is not fully reduced, if tension is placed on the sutures themselves to pull the bones into position and if a certain amount of play is allowed between the bones, the method is likely to fail

In some cases where the fracture can be brought together without much tension the cerclage may be done with kangaroo tendon or with chromic catgut After cerclage, it is always wise to put the limb in a plaster case as the mechanical hold of the wire or band is weak

The closure of the wound and the after treatment are the same as have already been described

6 Fixation by Intramedullary Pegs

The fixation of a fracture by intramedullary bone pegs represents the simplest and easiest form of operation for bone union

The peg when made of bone, is readily incorporated into and

absorbed by the human bone-tissue, and, being placed in the axis of the bone, automatically secures correct apposition and alignment The insertion of the peg only requires the exposure of the fractured ends and only a small extent of their surfaces

Indications.—The operation is indicated by an almost transverse fracture, without comminution in the shaft of a long bone, or at the junction between the shaft and the extremity, when the fracture cannot be accurately replaced by non-operative methods It is *particularly useful in fractures of the forearm bones and of the shaft of the femur*

Instruments required.—In addition to the bone set (p 288), there will be needed bone pegs of a suitable size and a set of twist-drills with a handle The pegs which may be needed are of the following sizes —

$\frac{1}{8}$ in by 1 in	$\frac{7}{32}$ in by $1\frac{1}{2}$ in	$\frac{3}{8}$ in by 3 in
$\frac{5}{32}$ in by 1 in	$\frac{1}{4}$ in by 2 in	$\frac{7}{16}$ in by 3 in
$\frac{3}{16}$ in by $1\frac{1}{2}$ in	$\frac{5}{16}$ in by 2 in	$\frac{1}{2}$ in by 4 in

The smaller sizes should be made of ivory and the larger of bone Each peg is provided with a central stop or ridge (Fig 121) to prevent its being thrust too far down either fragment

Technique.—A short incision is made over the site of fracture, and each fragment is seized by a separate pair of bone-holding forceps which not only serve to hold the bone during subsequent manipulation, but also help to prevent the fragments from splitting on insertion of the peg Each fragment in turn is brought up into the wound, and its marrow cavity drilled by twist-drills of gradually increasing size, until the drill is felt to be biting fairly dense bone The

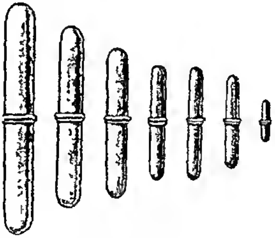


Fig 121 —Ivory or bone pegs

other fragment having been treated similarly, a peg corresponding in size to the largest drill is driven into one fragment up to the central stop Great care must be taken to see that the peg just securely fits the prepared medullary channel, if it is too large the bone-end will be broken up when the peg is driven home The other fragment is then drawn out of the wound and set at an angle to the protruding peg, with the end of which it is made to engage The two pieces of bone are then drawn away from one another, while the angle at their junction, formed by the peg, is pressed down so as to bring the whole bone into one line (Fig 122) When this has been done the peg will slip into place and, before it is pushed quite home, the orientation of

the fragments must so be adjusted in respect of rotation that they exactly interlock If the tension of the soft parts is too great to allow manipulation of the second fragment over the peg, the latter should be cut short It is not necessary to preserve more than about ½–1 in of the end of the peg to secure the object of the operation—that is the accurate end-to end apposition of the fragments Angulation must be prevented by proper external splinting

In the *humerus*, this pegging operation may be useful for a fracture of the surgical neck, or of the middle of the shaft If it is used, how-ever in the latter situation, some special precaution should be taken to prevent the weight of the arm dragging on the junction, as the peg affords no security against separation of the fragments The simplest precaution consists in placing the arm on an abduction splint, but this is somewhat irksome if it has to be continued for more than a few weeks A more exact precaution consists in passing a transverse pin or nail right through the bone and the peg, above and below the fracture This will serve to protect the fragments, not only from being pulled apart but also from being rotated It is particularly necessary to make this addition to the simple peg when the latter is used in delayed union In such cases there is but little muscle tension, and there is usually a definite gap between the bones, which will be still larger when the fibrous tissue filling the fracture has been cut away

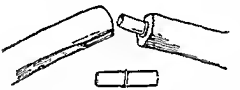


Fig 122 —Insertion of short bone peg

In the *radius and ulna*, if the fracture is transverse and not com minuted, the method is ideal because of its simplicity, and also because of the small injury done to the surrounding parts If the two bones are fractured at the same level, it is possible to expose both by a single curved incision on the back of the arm The proximal fragment of each bone is fitted with a peg and the distal fragments are then manipulated into position simultaneously In the after-care of forearm fractures thus treated, the limb should be put up in a plaster-of Paris case extending from the knuckles to the deltoid insertion, the elbow being at a right angle, the forearm midway between pronation and supination and the hand dorsiflexed The plaster case is cut into an inner and an outer half at the end of ten days so that movements of the fingers wrist and elbow may be begun but rotation of the forearm should not be allowed for four weeks

When used for the *femur* the pegging method is in many cases the simplest and most efficient means of operative treatment It is best suited to transverse fractures of the middle of the shaft—that is, where the marrow cavity is well defined It will always require an efficient caliper splint for about six months to prevent bending of the shaft during the period of early soft union The *tibia* is only suitable for a peg in the lower half, the upper part having a marrow cavity which is too large and not adapted for a circular peg

7 Nailing Methods

A small portion of bone may be fixed on to the main shaft by sutures or nails Nailing has the merit of simplicity and efficiency It may be performed to remedy fractures such as the separation of the great tuberosity of the humerus one of the epicondyles, the tubercle of the tibia, or one of the small bony processes about the ankle joint Or it may be used to affix a piece of bone which has been deliberately cut from its place during a surgical operation For example, the tip of the olecranon may be removed in order to expose the back of the humerus the great trochanter may be chiselled off from the femur to expose the hip, or the tubercle of the tibia may be turned up to gain access to the knee joint In each case the separated piece of bone is most conveniently refixed by a nail It is not necessary to give a detailed description of so simple an operation, but the nail must be described For most purposes a small carpenter's nail answers perfectly well It gives strong and firm fixation, and remains in place indefinitely For small, delicate pieces of bone like a separated epicondyle of a child a fine wire nail is best, when, on the other hand, a comparatively large piece of bone has to be fixed to the cancellous extremity, it is better to use a stout bone nail of square section, the reason being that such a nail will afford more secure contact and a firmer grip of the open bony tissue In inserting a nail into cancellous bone, it is not necessary to drill a hole, but the pointed nail should be hammered directly into place

Nails so used are much to be preferred to long carpenter's screws, which can never be driven tightly without tearing the soft cancellous tissue When this happens the screw lies loose, and even if temporary fixation is secured, the screw will usually have to be removed later

There is a third way in which a long nail or transfixion pin can be used to fix a fracture This is to leave the end of the pin projecting out of the limb, to be removed later Take for example, an oblique fracture of the tibia in which traction has reduced the shortening but has left some lateral displacement The site of the fracture is exposed and the bone ends adjusted A long nail or transfixion pin is made to pierce both fragments, and preferably this nail is introduced through a part of the soft tissues other than the main wound The wound is sewn up and the leg is encased in plaster, through which the end of the pin projects The pin is removed at the end of two or three weeks

FRACTURE OF THE NECK OF THE FEMUR

Fractures of the neck of the femur are divided into two main classes, the *cervical,* those in which the true neck is broken, and the *pertrochanteric,* those in which the fracture runs through the mass of the trochanter at the base of the neck The latter result from great direct violence are associated with much deformity (shortening and angulation), and undergo rapid bony union If unimpacted they should be treated by skeletal traction in a position of flexion and

abduction of the hip If impacted it is essential to disimpact before applying traction This can usually be done by forcible abduction making counter pressure at the point of fracture

Transcervical fractures often occur in old patients from trivial violence At first there may not be much deformity but there is a great liability to non union Whitman's method of fixation in a large plaster of Paris spica is long tedious and very uncertain Fixation by the Smith Petersen nail has now become the recognized method of treatment because of its simplicity and the rapid restoration of function It can be safely carried out in the majority of patients even those of advanced years and feeble vitality

Smith Petersen's operation —The essential of this method is the nail (*Fig* 123) which is made of stainless steel in various lengths (3 to 5 in) It consists of a head and a shaft the latter being made of three radiating

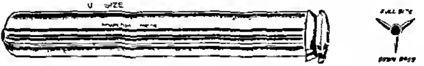


Fig 123 —Smith Petersen's nail (Watson Jones pattern with central canal for guide drill) (*a*) Cross section

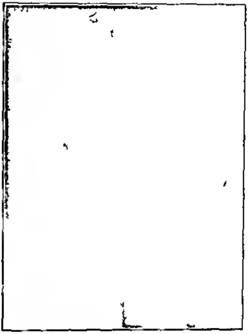
blades of thin steel each about ¼ in wide The modern pattern is perforated in its long axis by a channel which takes a guide wire or drill If this nail is thrust truly home through the base of the great trochanter and along the axis of the neck of the femur into the head of the bone right up to within ¼ in of the articular surface and if the fracture is firmly impacted it will be so held by the three-flanged nail as to give perfect fixation and the patient can begin to flex the hip at once and can get up within a few days The nail may be introduced by open operation or by a blind method using wires or a drill to guide it into position

The open operation —This should only be done in the comparatively young and vigorous patient and especially for sub-capital fractures in which the small fragment is difficult to control except by direct approach

Instruments required —The ordinary dissecting instrument a graduated *metal measure* for estimating the length of the nail (Watson Jones) Smith Petersen nails of various lengths guide drill hammer punch impactor (Figs 124 125 126)

Technique —An incision 8 in long (Fig 127A) is made from the anterior superior spine down to the tip of the great trochanter and then down the upper part of the shaft of the femur The femur and the hip-joint are exposed between the tensor fasciæ femoris and the gluteus medius and the hip-joint and the line of fracture are exposed by splitting the capsule (*Fig* 127B) The guide drill is thrust into

Woman aged forty four. Fracture of the neck of the femur two years after accident. Condition immediately before operation



Same case three weeks after proximal pegging

Same case six months after proximal pegging

Same case eighteen months after proximal pegging. Legs same length, no pain, perfect function, walked with absolutely normal gait

FRACTURE OF NECK OF FEMUR

PLATE I

(a) Intra thecal extramedullary neurofibroma

(b) Intra thecal extramedullary meningioma

(c) Case of meningitis circumscripta serosa

Note the helmet shaped appearance of the blob in the tumour cases and its convex lower limit in the case of arachnoiditis

PLATE II —Appearances after lipiodol injection by the cisternal route

Fig 124 —Graduated metal bar placed on outer surface of thigh on same level as femur before taking antero-posterior X ray It will give the length of the nail required in quarter inches

Fig 125 —Punch placed over the drill on to the head of the nail

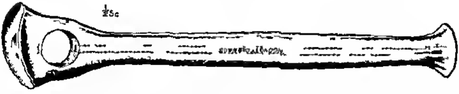
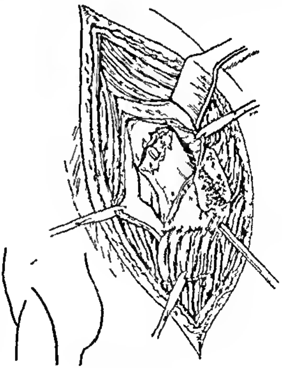


Fig 126 —Impactor placed against the outer surface of the femur over the head of the nail and drill and struck so as to force the neck against the head

the base of the trochanter about ¾ in below its most prominent lateral point and made to emerge in the centre of the fractured surface of the broken neck The bone is manipulated until the fractured surfaces are in perfect apposition and the guide drill is then thrust into the head A nail of the correct length is taken the length having been ascertained previously by means of a graduated metal measure (Fig 124) placed on the side of the thigh at the same depth as the femur before the anterior posterior X ray The nail is threaded on to the guide drill and hammered home by the punch (Fig 125) and the fracture is finally forced together by the impactor (Fig 126) The capsule and muscles are closed by deep stitches and the skin by silkworm gut No splint or plaster is used after the operation but outward rotation of the leg is prevented by slinging up the flexed knee



A B

Fig 127 —Watson Jones operation for fractured neck of femur

The advantages of this

open operation are (1) that it is not dependent on X-ray evidence to ensure the correct placing of the nail, and (2) that the exposure of the line of fracture gives an opportunity for exact reduction and for the removal of any interposed soft tissue Its disadvantage is that it involves a serious operation and an opening into the hip joint This makes it unsuitable for feeble, aged patients

The blind operation. Using several wire guides —In this operation, suggested by Sven Johanson, the nail is guided into position under X ray control The fracture is first reduced accurately, as proved by frontal and lateral X rays and three or four Kirschner s wires are then thrust into the neck of the femur through the base of the trochanter X-rays are taken to show which of the guide wires is in the true axis of the neck All other wires are withdrawn and the perforated nail is driven into the femur over the remaining wire

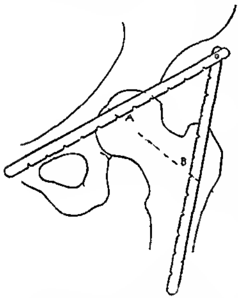


Fig 128 —Metal caliper mechanical guide for use in blind operation

In actual practice this method may be very tedious and unsatisfactory

Using a mechanical guide —The exact line and depth of the neck of the femur may be accurately gauged by a mechanical guide Many such guides have been invented, and it will suffice to describe one of the simple types and its use In the first place the fracture must be exactly reduced by traction and this reduction verified by X-rays taken in two planes The line and length of the neck of the femur are marked and measured by a graduated two limbed caliper (Fig 128) The hinged metal caliper is placed on the patient s skin with its angle below and medial to the anterior superior spine , one limb lies parallel with the fold of the groin and the other vertically down the middle of the thigh It is fastened by adhesive plaster to the skin, and an X-ray is taken Two points have to be marked on the skin (*a*) the mid-point of the head of the femur, and (*b*) the point where the axis of the neck and the axis of the shaft cross These points can be recognized on the X-rays, and their relationship to the notches on the compass guide will enable them to be marked on the skin

The drill guide (Fig 129) consists of three vertical rods attached to a horizontal bar The two rods which are pointers to the line of the neck are sharp one (A) fixed at the end of the horizontal bar, is to mark the centre of the head of the femur, and the second (B), which slides along the horizontal bar, is to mark the point where the axis

of the neck and the shaft cross The third vertical rod (C) which also slides along the horizontal bar, holds a tubular drill carrier A drill guided by the drill carrier must pass along the line between A and B, the points resting on the head of the femur and the neck when viewed from the front, i e, in the vertical plane It will also follow

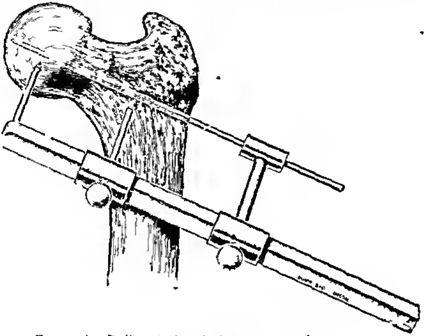


Fig 129A —Drill guide for blind operation on femur

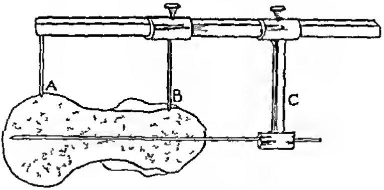


Fig 129B —Drill guide applied.

the line of the neck of the femur correctly in the horizontal plane This is secured by the fact that the length of the three vertical rods are 2 in, 2¼ in and 2¾ in respectively This will be easily understood by reference to Fig 129B These measurements are in accordance with the fact that the head of the femur is ¼ in nearer the surface than the front of the neck of the femur, and that the latter is ½ in more superficial than the axis of the neck

The operation —The fracture having been pulled into good position as proved by frontal and lateral X rays and the two points A and B having been marked on the patient's skin the operation can begin In dealing with feeble old patients there is a good reason for doing the operation in bed rather than moving them at the last moment on to an operating table Moving the patient on to a table involves taking the X rays and marking the skin points after the move Anæsthesia is by gas and oxygen The skin is punctured by a tenotomy knife over the points A and B and the pointed rods of the drill guide having been adapted to the proper distance between A and B and fixed are thrust vertically through the skin and soft parts until they impinge on the bone beneath The vertical rod C is then slid up the horizontal bar until it touches the skin of the outer side of the thigh A pointed drill $\frac{3}{32}$ in in diameter is then inserted into the carrier thrust into the leg and drilled right up the neck into the head of the femur It is rather an advantage if this drill transfixes the acetabulum as it will thus steady the head when the nail is driven in The drill guide is then taken away leaving the drill in place An incision 2 in long is made through the skin with the drill as its centre and this is deepened down to the bone The cannulated nail is passed over the drill and hammered into place by the perforated punch The fragments of the fracture are forced together by a few strokes on the impactor the drill is removed and the wound closed Two X rays are taken before anæsthesia is concluded to ensure that the nail lies in the true axis of the neck of the femur and that it has been driven in far enough and not too far The actual time occupied by the operation is only about five minutes it is without shock and without loss of blood and for this reason can be safely used for old and feeble patients

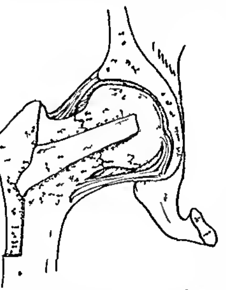


Fig 130 Diagrammatic section showing the structure of the bone graft. The graft is composed of a major amount of spongy bone encouraging early vascularization and only a sufficient amount of cortical bone to maintain firm fixation.

(*After Fl. Jones modified.*)

After treatment —This is the same as after the open operation no splint being used and the knee being kept slightly flexed so that the leg cannot rotate outwards Exercises of ankle knee and hip are undertaken after a few days At the end of a week the patient gets up with crutches putting the foot to the ground within about six weeks

Ellis Jones operation —Although this was designed before the Smith Petersen nail operation it still has a place in surgical technique It is especially indicated

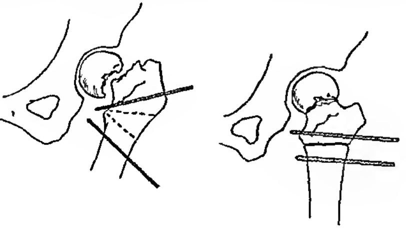
where efficient treatment has been postponed for several weeks or months and where it is desirable to expose the seat of fracture remove intervening tissue and adjust the position A long incision is made on the outer side of the great trochanter, which is fully exposed A piece of bone 4–5 in long and ½–¾ in thick is cut vertically from this part of the bone The neck of the femur and the area of the fracture are exposed and can be refreshed and then placed in accurate position After this the bone graft is driven up into a suitable hole drilled in the axis of the neck of the femur (Fig 130) The wound having been closed a plaster of Paris spica must be applied and kept in position for about three months

OPERATIONS FOR UNUNITED FRACTURES OF THE NECK OF THE FEMUR

Nailing operations can be carried out for ununited fractures even if some period has elapsed provided that the head has not lost its vitality (shown by the X ray appearance) and that the neck has not *been absorbed But it cannot be too strongly emphasized that the* chances of success will be greatly diminished by delay because of sclerotic changes at the fracture surfaces When however all hope of bony union is lost it is still possible to do something to alleviate the pain and lameness which will otherwise accompany an ununited fracture There are three possible operations each of which has its special indications

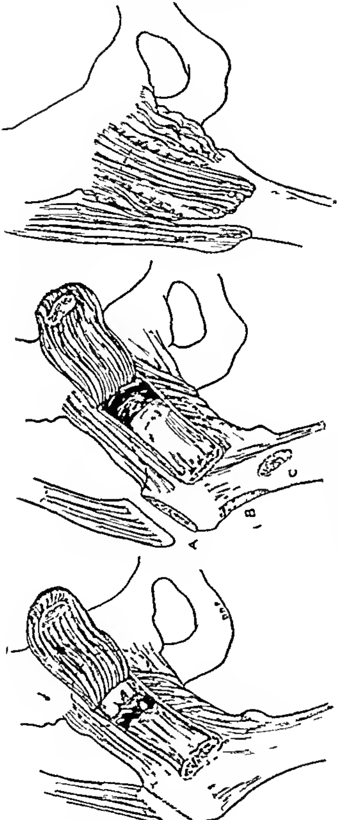
Lorenz's bifurcation osteotomy.—This operation which is described below (*see* p 265) is the method of choice for old and feeble patients It is simple and free from shock

Schanz's cuneiform osteotomy.—In this a more precise reconstruction of the upper end of the femur is carried out Two stout transfixion pins are driven into the upper end of the femur The upper goes through the trochanter into the base of the neck the other through the upper part of the shaft They are set at an open angle



A B

Fig 131 —Schanz osteotomy



132A 132B 133

Figs. 132 and 133.—Reconstructive operation for ununited fracture of neck of femur

so that when the wedge has been removed between them they will be parallel (Fig 131A) A wedge is cut from the bone between the two pins and the gap is closed by drawing the pins together (Fig 131B) The projecting ends of the pins are incorporated in a plaster spica The effect of this operation is to rotate the upper end of the femur to lie vertically below the head In some cases bony union has eventually occurred at the seat of the fracture, owing to the pressure of the broken hones on one another

Whitman's reconstructive operation.—In this the head of the bone is removed from its socket and the neck of the femur is placed in the acetabulum It is only suitable for comparatively young and vigorous patients An incision is made along the anterior 2 in of the iliac crest and down the line of the sartorius for 4 in The hip-joint is exposed by turning the sartorius medially and the tensor fasciæ (femoris) and gluteus medius laterally The capsule is opened by chiselling off its lower attachment to the inter-trochanteric line and turning up the anterior portion (Fig 132) The head is removed and the neck brought forward and rounded The tip of the great trochanter is cut off and re attached to the shaft at a lower level The capsule is similarly attached at a lower level so as to sling the femur up in its new position (Fig 133) The wound having been sutured, the leg is put up in an abducted position and fixed in a plaster cast

8 Suturing by Wire or other Material

There are two fractures in which wire sutures remain the simplest and most efficient method of treatment, viz fractures of the olecranon and the patella They are occasionally of use in fractures of the mandible

FRACTURE OF THE OLECRANON

All recent cases of this injury, with complete separation of the small fragment, should be treated by open operation, unless the patient is old and debilitated

Instruments required are those of the bone set (p 233), together with some hand drills and some No 16 soft iron wire

Technique.—The arm is placed across the patient's chest, a U-shaped incision with the bend downwards is made over the elbow, the sides of the U beginning just above the back of the condyles, and the lower part of the incision crossing the upper end of the ulna The flap thus marked out is turned up as far as the point of the elbow, the broken piece of olecranon is defined by turning aside the torn aponeurosis covering the fracture The bloodclot is removed from between the fragments and the cavity of the joint, and the fragments are then brought down into accurate apposition with the shaft (Fig 134) Holes are made from side to side through the shaft and the separated process that through the process being as near to the superior surface as possible, while that through the shaft is about ½ in from the fracture Two wire loops are passed through this pair of holes in reverse

directions The *fragment* is held in exact apposition and the two loops of wire are tightened and twisted simultaneously A single loop of wire is often sufficient but the advantage of the double loop is that the two sides of the fragment being pulled with equal tension there will be no tendency to lateral tilting A cut should be made in the aponeurosis for the portions of wire which lie at the side of the fracture and into this cut the twisted ends should be turned after cutting short The aponeurosis is sewn together over the fracture

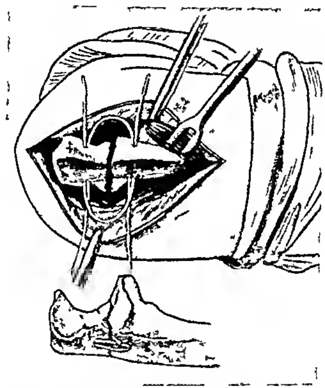


Fig 134 —Fracture of olecranon sutured by two wire loops

(Note —This was drawn from a case in which an external bow-shaped incision was used but in practice it is better to employ a U-shaped incision.)

and also over the wire so that the wire lies completely buried After the wound is sutured the arm is placed in a sling in a position of flexion of the elbow without any splint From the third day onwards the slings should be removed at least once a day and the hand dropped as low as can be borne without pain and then raised to its former position with the aid of the uninjured hand At the end of ten days or a fortnight when the wound has healed the patient can use the arm for simple every day actions but it should not be allowed to *hang* at the side for a further period of two weeks

Many surgeons use chromicized catgut instead of wire but I greatly prefer wire because movements can be undertaken early without any fear of displacement

FRACTURE OF THE PATELLA

All fractures of the patella with marked displacement of the fragments, such as result from muscular violence, should be subjected to open operation, performed within the first week after the accident, and before contraction of the quadriceps has occurred

Wiring the patella.—Running the wire as a circular suture, almost surrounding the bone, like a rim round a wheel, is better than placing vertical loops in the way often described and figured Not only is it easier and more efficient, but it allows the leg to be used very shortly after the operation, without fear of the wire breaking or cutting out The patella is particularly unsuited for plating, as the plate would have to be placed just beneath the skin and the screws would have no dense bone in which to hold

Instruments required.—The same as those indicated for the fracture of *the olecranon but a thicker pattern of iron wire No 11* or *No 12 should* be used

Technique—A U shaped incision is made, surrounding the patella at the side and above The flap is turned down to expose the fracture The fragments are drawn farther apart while the knee is fully flexed, and the joint is cleared of bloodclot or small fragments of broken cartilage The torn aponeurosis is lifted from the fractured surfaces, and the fragments are brought accurately together the knee being extended Holes are drilled in the patella from side to side, as near to the upper and lower margins of the bone as is practicable Grooves are cut in the soft tissues at the side of the patella, from the upper to the lower hole Double loops of wire are passed in reverse directions the loops simultaneously tightened twisted, and cut short while all the time an assistant holds the two fragments firmly together The aponeurosis is sewn over the fracture and, where it has been torn, at the sides of the patella After suture of the incision the leg is placed in slight flexion over a pillow It is raised to a straight position once daily after the third day and when the wound has healed at the end of about a fortnight, the patient is allowed up

Many surgeons prefer to use chromic catgut for suture of the patella In this operation only the aponeurosis over and at the sides of the broken bone is sewn together, but a stout kangaroo tendon can also be made to encircle the whole bone If this technique is employed, the leg must be put up in plaster for six weeks, to give time for union

The operation is considerably more difficult if some time has elapsed since the fracture so that the upper fragment has become drawn up 2 in or more away from the lower It must then be done in two stages In the first, the fracture having been exposed in the usual way, the upper fragment is detached, together with the lower part of the quadriceps muscle, from the front of the femur, pulled down as far as possible, and sutured to the lower fragment by a stout wire loop, which is tightened so as to obtain the greatest possible tension the structures

will bear This probably brings the upper fragments down for about half the necessary distance and the wound is then closed

In the next stage to be performed a few days later the wound is re opened and it will be found that the tension on the upper fragment has been so far reduced as to permit it to be completely replaced in correct position (Fig 135)

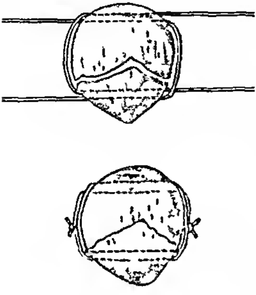


Fig 135 —Wiring patella

An easier way of performing the first stage is to use a small transfixion pin which can be passed through the upper fragment without an open incision and to attach a 10 lb traction to this pin for a few days

Fascial suture of the patella —The only drawback to the wire suturing of the patella is that it often leads to some osteitis which causes thickening and roughening of the knee-cap For this reason many prefer to be content with suturing the aponeurosis with chromic catgut but this will require a rather longer immobilization in an extended position Probably a strip of fascia lata is the best A J shaped incision is made the long limb of which runs upwards from the knee on the outer side of the leg in the line of the ilio tibial band and the curved part crosses below the knee across the ligamentum patellæ The fracture having been exposed and bloodclot removed a strip of fascia lata is cut 6 inches long and ¾ inch wide This is separated above but left in its natural attachment to the outer tuberosity of the tibia below This fascial strip is then pulled through the quadriceps tendon just above the upper patellar fragment to the inner side of the knee by means of long forceps thrust through the tendon just above the patella Similarly the end of the fascial strip is pulled through the ligamentum patellæ to the outer side of the knee The fascia now surrounds the patella the two fragments of which are adjusted into accurate apposition whilst the fascia is pulled tight The end of the fascia is now twisted round the fixed base and securely sewn by fine kangaroo tendon (Fig 136)

In this way not only is the suturing carried out by a very strong band of living fascia but also the fixed end of the ilio tibial band affords a second natural insertion for the quadriceps into the tibia This method is to be employed in all old fractures of the patella because although the fragments may not be brought together yet the upper

fragment and the tendon of the quadriceps will be given a firm new attachment to the head of the tibia

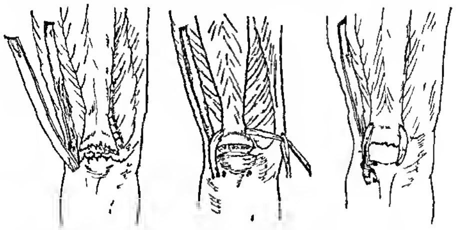


Fig 136 —Fascial suture of patella

Removal of the patella —Brooke* has shown that rapid restoration of function and a perfectly strong knee will follow excision of the patella If this is confirmed by other workers, this method will become that of choice in all recent cases

The patella is not in reality a part of the extensor tendon and its aponeurosis but is a sesamoid bone lying behind these structures When the patella is broken by indirect violence the aponeurosis over it is torn together with the strong lateral expansions To restore the extensor tendon, it is necessary to unite the torn aponeurosis, while the fragments of the bone which tend to hinder this union are better removed

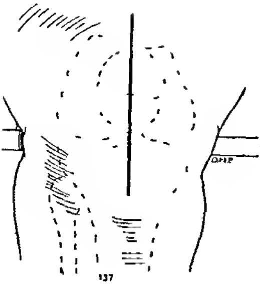
The operation —A vertical incision about 4 in long is made over the front of the knee and the patella with its aponeurotic covering is exposed (Figs 137, 138) The two fragments of the bone are then shelled out and removed (Fig 139) The aponeurosis is sutured with interrupted silk sutures (Fig 140), special attention being paid to the strong lateral expansions on either side of the patellar bed It is through these expansions that the extensor action of the quadriceps is chiefly transmitted to the patellar ligament below A firm domette bandage is applied over a thick layer of cotton wool No other splint is used After 2 days the patient is allowed up After 10 days the stitches are removed and the dressing discontinued The patient is able to return to work in 2 to 6 weeks from the date of operation

After this operation both the strength and mobility of the knee are perfectly restored and equal to those of the sound leg

9 Bone grafting for Recent Fractures

It has been suggested that the operation for fixing recent fractures should consist in bridging the fracture by means of a strip of bone cut

* B J Journ Surg April 1937 xxv 733



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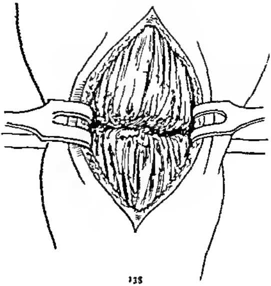

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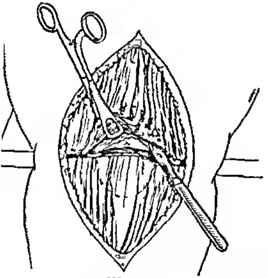

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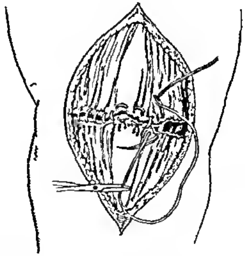

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Figs 137 138 139 140—Excision of patella for fracture.

Fig 137—The incision Fig 138—Aponeurosis turned in between fragments
Fig 139—Clearing fragments for removal. Fig 140—Suturing the tendon and aponeurosis

from one fragment the idea which forms the basis of this suggestion being that of repairing the bone tissue by living bone and so hastening the natural process of repair But this idea rather ignores the mechanical problems involved A bone graft placed on the outside of a bone takes much longer to acquire firm fixation than does the normal process of fracture repair The limb will therefore have to be fixed in plaster for a long period In the majority of cases, this method is more complicated than is necessary for a simple displacement, while in difficult cases it does not afford a sufficiently secure fixation

OPERATIONS FOR MALUNITED FRACTURES

Before describing in detail operative procedures for the correction of malunited fractures, it is necessary to consider the conditions of the bones and soft parts in this deformity A malunited fracture has three components viz (1) *Shortening* from overlapping of the fragments, this is much more important in the lower than the upper limb (2) *Angulation* with or without lateral displacement this is always a serious matter because the angulation of the bone always disturbs the mechanics of the nearest joint (3) *Rotation* this is chiefly important in fractures of the radius and of the leg bones, in the former it disturbs pronation and supination, and in the latter it turns the foot inwards or outwards

Union of bone is considered to have occurred when there is more or less solid continuity between the fragments But this union occurs in two stages—by callus and by bone In the first stage the fragments retain their firm structure and clear outline while the uniting material is plastic, varying in consistence from soft granulation tissue slightly impregnated with bone salts to dense callus almost like bone In the second stage the fragments have lost their clear outline and the dense substance has been replaced for a time by more open vascular bone, the callus has become harder, and is of the same density as the fragments which it unites Finally, the whole area of bone has become more dense than normal, and the original architecture has been altered by the laying down of new lines of dense bone and the removal of projecting processes

These two stages of repair, that by callus and that by bone, merge gradually into one another but for practical purposes the distinction between them may be made by X-rays, which in the early stage show the original fragments clearly defined, while the callus is much less dense, in the later stage the fragments are seen rounded off and the distinction between bone and callus is ill-defined

In dealing with malunited fractures it is necessary to distinguish between cases which are still in a state of callus repair and those in which ossification with reconstruction of bone has taken place In the former type, if the deformity is such as seriously to interfere with function, the bone should be re-fractured—that is to say, the callus union should be broken down and the limb put up in a correct position It is easy after re-fracture of the callus to correct rotation or angulation by suit-

able manipulation but it may be very difficult to overcome shortening because all the muscles and soft parts have become adapted by contraction to the shortened state It is in such a condition that powerful axial traction applied to a transfixion pin will be clearly indicated For an adult femur 60 lb may be applied and for a tibia 30 lb these weights being used for about 4 to 6 days and then reduced to 10 and 20 respectively

It is very unwise to attempt a reconstructive open operation on a seriously malunited fracture at one sitting It is desperately difficult and dangerous to attempt by a single operative act to lengthen a femur which has 2 inches of shortening whereas it is easy and free from danger to do this by a gradual force acting continuously for several days

When the fracture has reached a stage of ossification it is out of the question to do a reconstructive operation Not only have the ends of the fragments become structurally altered but the soft tissues muscles vessels and nerves have become adaptively shortened so as to make a restitution of the original bone-form impossible Of the various elements of displacement which may constitute the deformity of malunion angulation is by far the most important It not only increases the shortening of the bone but throws out of line the joints at either end so that secondary deformities will arise to compensate for the primary Two common examples will make this clear In fractures through the neck or upper third of the femur the bone may have become united in a position of adduction which produces a varoid deformity of the hip tilting of the pelvis and curvature of the spine. Similarly internal angulation of the tibia and fibula at their lower ends will produce eversion of the foot and flattening of the arch Sometimes the evil results of malunion may best be overcome by arthrodesis of a neighbouring joint (*see* Operations on Joints p 106)

Operations for Angular Deformity

The treatment of angular deformity is to divide the bone by an osteotomy which may be either simple cuneiform or curved

Simple osteotomy —The bone is divided at or near the seat of fracture and then forcibly straightened If the seat of fracture has produced a large mass of bony thickening it is usually easier and just as efficient to divide the bone above or below this thickening

Instruments required —Knife scissors dissecting forceps artery forceps periosteal elevators Adams saw osteotome hammer needles and sutures Tenotomy knives may also be required

Technique (Fig 141)—An incision about 1 in long is made over the bone where division is intended Beginners may be well advised to make a larger incision so as to see better what they are doing The incision is deepened to the bone and the periosteum raised sufficiently to insert the point of an Adams saw or the blade of an osteotome The knife is left in the incision with its point touching

the bone while the osteotome or saw is guided along it If the bone is not too thick division may be made by the osteotome alone but it is usually easier to divide the bone partly with the saw and partly with an osteotome and hammer the division being completed by breaking If rectification of the bone is strongly resisted by certain shortened muscles these should be divided by a subcutaneous tenotomy The wound having been sutured the limb is put up in plaster of Paris or on a suitable splint with the deformity rather over corrected After operations on the femur, the plaster is left for 6 weeks and a

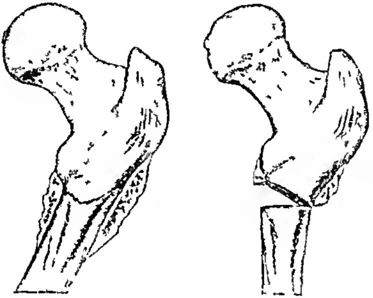


Fig 141 —Simple osteotomy of upper end of femur viewed from behind (the callus has become partly broken away)

walking caliper used for (months and after operations on the tibia 4 weeks in plaster should be followed by side irons fitted to the heel of the shoe for about 4 months

Cuneiform osteotomy. Technique —In this operation a more precise correction of the deformity is attempted by removing a wedge-shaped piece of bone from the convexity of the curve the angle of the wedge being the same as the amount of the angular deformity which it is intended to correct This angle should be measured beforehand and a small piece of aluminium plate cut to represent it It will be necessary to expose the site of the deformity by an incision several inches in length and it is often convenient to make this curved so as to raise a flap and thus avoid an incision which will lie on the divided bone The bone having been exposed saw cuts are made converging towards one another so as to meet at the concave border of the curved bone and angulated to one another as already estimated By this means a wedge-shaped piece of bone is separated and this should be removed

The bone can then be straightened and put up as before (Fig 142) Schanz s osteotomy is described on p 253

In actual practice, simple osteotomy is usually satisfactory for the

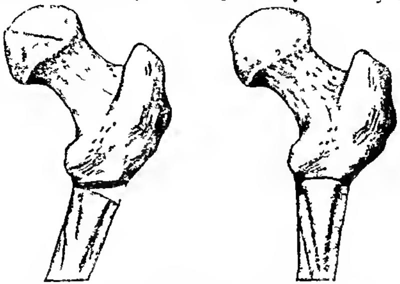


Fig 142 —Cuneiform osteotomy of femur, viewed from behind

upper end of the femur Cuneiform osteotomy is done for deformities of the tibia especially for malunion after Pott s fracture

Curved osteotomy.—This is very useful for flexion deformity of the knee In addition to the ordinary instruments a fine band or

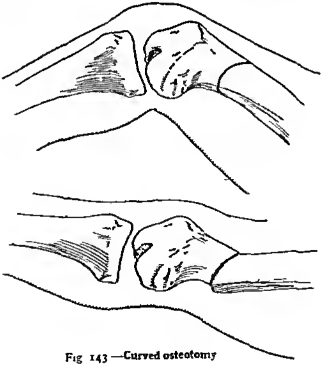


Fig 143 —Curved osteotomy

fretsaw is needed *The lower end of the femur is exposed by two* lateral incisions above the condyles the vasti muscles being pulled forwards The saw is passed behind the quadriceps muscle in front of the femur and a curved saw cut is made 3 inches above the knee with the convexity downwards the curve being that of the natural line of the condyles (Fig 143) After the bone has been divided the leg can be straightened the cut surfaces of the osteotomy sliding upon one another without making any gap or angulation

Bifurcation osteotomy (Lorenz) (Fig 144)—This is a most useful operation for any condition of adduction deformity of the hip whether

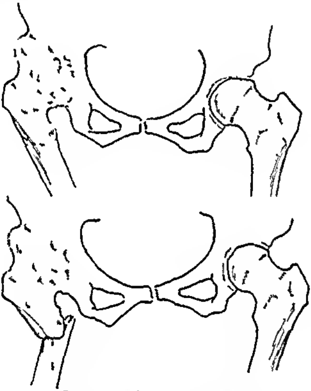


Fig 144 —Bifurcation osteotomy

this results from ankylosis of the joint faulty position unreduced congenital dislocation or malunion of fracture through the base of the neck or trochanter

A simple osteotomy is done through a small incision at the base of the great trochanter the femur being divided just below the small trochanter The thigh is then abducted until its axis points to the umbilicus and the shaft of the bone is pushed in towards the pelvis The limb is put up in plaster *for 2 or 3 months The effect of this* operation is to give functional lengthening to the legs by tilting the pelvis downwards on the affected side Also the body weight rests more directly on the shaft of the femur and is borne by the wide support of the Y into which the upper part of the femur has been shaped

Operations for Lengthening Bones

In a malunited fracture with great overlapping of the fragments and consequent shortening a sharp distinction must be drawn between recent conditions with callus union and older conditions which have fully ossified In the former only will reconstruction be possible and it is usually wiser to be content with transfixion and traction after breaking down the fracture The problem now to be considered however is the possibility of lengthening a bone which as the result of a fracture or deficient growth is so much shorter than normal as to constitute a serious functional defect Such a problem will only occur in connection with the leg bones because a difference in length between two arms is not of any special moment As there are so many mechanical means by which alterations in length may be overcome it is probably only in exceptional circumstances that operative measures will be justifiable

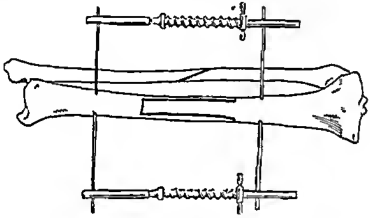


Fig 145 —Bone lengthening by Abbott s apparatus

The operation is difficult and recovery tedious The bone to be dealt with is hard thick and deformed as the result of an injury or slight and fragile as the result of paralysis The soft tissues will have to be stretched and this can only be done to a limited extent Thus in an adult femur it is seldom possible to get a lengthening of more than 1–1½ in

Instruments required —In addition to the bone set a good fretsaw and a fine keyhole saw motor drills and some special distraction apparatus

Technique —Supposing the operation to be done for the *femur* the shaft of the bone is exposed in its middle portion by an anterior incision at the outer border of the rectus muscle The incision will have to be long and the muscles must be freely separated from the exposed portion of the bone and particularly from the back along the linea aspera The simplest method of dividing the bone is to make a long oblique division—that is to say about 3 in long in a femur 1 in thick But if the operation is undertaken at all it is better to attempt a more

precise method This consists in a long ⌉⌊-shaped division of the bone Two transverse cuts are made through half the thickness of the bone, one through the front and the other through the back, these two cuts being 3 in apart from one another Then, by means of a fretsaw or a fine bandsaw, these two transverse cuts are joined by a longitudinal one The bone having been divided into two fragments with widely overlapping ends, the wound is closed and continuous traction applied The mechanism is different in the femur and the tibia In the femur the lower end is transfixed by a pin or taut wire with a metal horseshoe holder The limb is suspended in a Thomas s splint, and traction is applied by a weight or by a spring attached to the lower end of the splint In the lower leg bones, the fibula is obliquely divided and the tibia divided by a ⌉⌊-shaped division Double transfixion is applied, and lateral distraction bars are fixed so as to exercise a pull of the fragments away from one another Abbott's apparatus (Fig 145) is comparatively simple * Harboush† and others have designed more complicated machines in which the transfixion is by taut wires above and below the bone division

Operations for Shortening Bones

It is much easier to shorten a bone than to lengthen it, and, paradoxical as it may at first seem, all the objects of the one operation may be equally well served by the other The primary object of altering the length of a bone is to make it of the same size as another bone with which it has to act as a pair, thus the two legs ought to be of approximately the same length, and the radius and ulna, and the tibia and fibula should also be equal Not only is the mechanical act of shortening easier than that of lengthening, but the vital conditions necessary for success are much more favourable Take, for example, unequal legs caused by a malunited fracture, tuberculous disease of the hip, or infantile paralysis In all these conditions the tissues of the longer leg will be sound, strong and healthy, whereas those of the short leg will be the reverse Similarly, in deformity of the forearm caused by a shortened radius, the ulna and its surroundings will be healthy, whereas the radius will be deformed or diseased So that if interference is necessary at all it may be wiser and safer to shorten the healthy bone rather than to attempt a lengthening operation in unfavourable conditions

Indications.—The operation may be considered when there is shortening of the femur or of the tibia of such an extent as to cause serious lameness or to necessitate wearing heavy apparatus, or when there is so much shortening of the radius as to produce marked deviation of the hand

Instruments required —The bone set (p 233)

Impaction operation.—In the femur, the best operation is one which impacts the shaft into the supracondylar region It makes a very strong union and does not require the use of foreign bodies

* L. C Abbott *Journ Bone Joint Surg* January 1927 ix 128
† *Ibid* October 1932 xiv 807

The femur is exposed on the outer side by a 6 inch incision, the centre of which is 4 inches above the knee The femur is divided just at the point where the shaft expands towards the condyles The distal end of the bones is bored with a half inch twist drill The proximal part of the femur is brought out of the wound and divided upwards by a longitudinal saw cut into an anterior and posterior

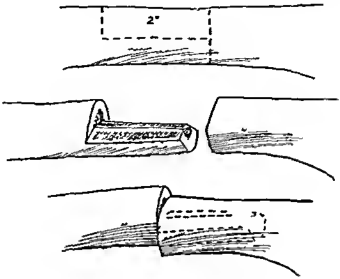


Fig 146 —Impaction operation

portion for as many inches as it is desired to shorten the bone (Fig 146) The anterior portion of the bone so divided is removed and the posterior part including the strong linea aspera is left as a projecting peg This is reduced by filing or chiselling until it will engage in the ½ inch hole It is impacted into the lower end of the bone and there retained by a transfixing ivory nail or a peg cut from the spare piece of bone removed from the shaft

OPERATIONS FOR OPEN (COMPOUND) FRACTURES

Open fractures are usually infected Sometimes the infection is slight in amount and in virulence as when the sharp end of a bone is merely driven through the skin At other times it is great as when a limb is run over and dirt is driven into the tissues

It cannot be too strongly emphasized that reconstructive operations involving wide exposure of infected tissues and the use of foreign bodies e g plates screws pegs etc are absolutely contra indicated If the infection is light, then the wound may be allowed to heal and the operation postponed If the infection is heavy, nothing but disaster e g extensive necrosis can result But there are two types of operation for infected open fractures which will be necessitated in all but the simplest type

Immediate wound toilette and suture.—This operation should be routine for all serious cases in which the patient comes for treatment within 12 hours of injury The principles are very simple, but it is often done badly because it is not attacked as a serious major operation The steps should be as follows (i) If the wound is small it is merely covered with an antiseptic pad, if larger it is lightly packed with iodine- or flavine soaked gauze The rest of the limb is then washed and shaved, and the skin disinfected (ii) The hands of the surgeon are then gloved and, if the wound is punctured, it must usually be enlarged, larger wounds are unpacked and cleaned up The edges of the torn and bruised skin are cut away, torn or frayed muscle and fascia are trimmed away, and all foreign bodies removed, together with any really detached bits of bone Comminuted fragments of bone which have any connection with the soft parts should all be preserved Any obviously damaged nerves or vessels are sutured or ligatured, but no special search should be made for them The surgeon's gloves are now changed and, while the wound is held widely opened, every recess should be carefully swabbed with 1-in-1000 flavine solution or thoroughly smeared with Bipp (bismuth, iodoform and paraffin in proportion 1 2 3) The original greasy Bipp does not readily spread on the tissues, but the bismuth and iodoform, in the original proportions made into a paste with a watery solution of 1 in-20 carbolic, answers most satisfactorily The wound is closed by interrupted sutures and the limb is put up by some efficient fixation method of which skeletal traction is the best Where the wound is very foul, or where the period since injury exceeds 12 hours it is wiser to pack the wound lightly with flavine soaked gauze and to leave the sutures untied Then if within a few days infection has subsided, delayed primary union may be expected and the sutures can be tied

Many surgeons rely solely on effective debridement and do not advise any irrigation of the wound or preparation of the skin by scrubbing or shaving Iodine is painted on to the skin only, the edges of the wound are excised, and skin towels are applied All potentially infected tissue is then cut away with a knife and the skin is sutured without drainage This applies only to fractures treated within six hours (Bohler)

Treatment by vaseline pack and plaster case (*Winnett Orr*)— In serious or chronic infection of an open fracture, where primary suture cannot be undertaken or has failed, Winnett Orr's method should be adopted In the common type affecting the tibia and fibula, the patient is placed on an extension frame, e g Hawley s table, and a transfixion-pin passed through the os calcis and the traction appliance adjusted The wound is enlarged enough to expose both fragments, and sufficient traction is applied to pull the bones apart The front portions of both bones are chiselled away so as to convert the whole wound into a funnel shaped cavity from which all loose granulating tissue is scraped away. The wound is tightly packed

with dry gauze until oozing has been checked and similarly treated with gauze soaked in iodine and lastly with spirit A clean dry cavity having been secured the whole is packed with gauze impregnated with vaseline A vaseline pad is placed over the surface and the limb covered with a layer of cotton wool If great traction has been necessary to pull the bones apart then a second transfixion pin is passed through the tibial crest just below the tubercle A plaster cast is applied over the leg from the toes to half way up the thigh including both transfixion pins The future conduct depends on the course the wound takes In the great majority of cases the plaster is left in position for 8 to 10 weeks The temperature will probably go up to 100° or 101° F for one or two days after the operation and then settle down to normal The transfixion pins are removed in four weeks The plaster case becomes stained with blood and discharge and there is an unpleasant odour But if the patient has no pain and the temperature is normal the smell can be disregarded

When the plaster is removed (after 8 or 10 weeks) it will be found that the vaseline pack has been extruded and the wound reduced to a small granulating surface

OPERATIONS FOR DELAYED UNION AND FOR UNUNITED FRACTURES

Beck's drilling—This is only suitable for cases of delayed union A short stout Kirschner s wire held in a chuck is used as the drill It is inserted at several points through the skin and down to the bone over the end of each fragment Then 6–10 drill holes are made through each point of insertion in different directions and if possible are made to transverse the line of fracture In the tibia for which this operation is most frequently used the patient is made to walk a day or two after the operation the leg being supported in a plaster case and walking iron This method has also been used with success in fractures of the carpal scaphoid

Ununited fractures as distinguished from mere conditions of delayed union may present either fibrous union or a false joint In both cases the bone-ends are sclerosed and thickened the end of the marrow cavity being filled with dense bone and the surfaces being smooth from simple eburnation or covered by a dense layer of fibro cartilage A thick envelope of fibrous tissue connects the bone-ends and if a false joint is present there is a definite cavity between the bone ends and inside the fibrous capsule filled with glairy fluid while velvety or villous projections from the capsule hang into the cavity Some of these projections may become separated and form loose bodies All operations for the cure of ununited fractures necessitate a preliminary removal of the whole of the fibrous tissue between the bone ends including the capsule of the false joint together with excision of the dense ends of the bone The removal of the bone ends is made necessary by the fact that these really represent scar tissue and are destitute of both blood vessels and bone cells and are therefore

incapable of repair The bone must be removed freely enough to expose bone tissue of more or less normal texture with a bleeding surface Similarly the capsule of fibrous tissue must be dissected away until normal bleeding soft parts are exposed all round the area of fracture and the marrow cavity is freely opened After this preliminary stage the subsequent steps differ in character and complexity according to the circumstances

Comminution and impaction —A further step in the same direction consists in breaking up the two ends of the bone by a chisel or bone

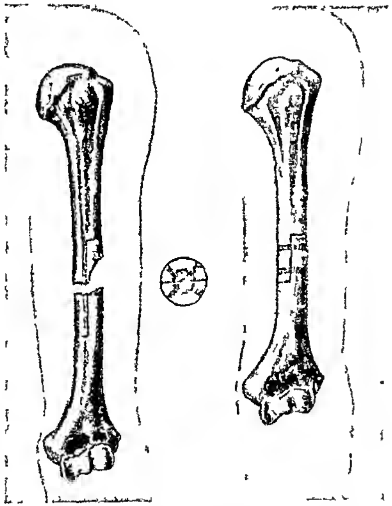


Fig 147 —Diagram of step cut operation for ununited humerus

cutting forceps and then impacting them so that the comminuted fragments shall be jammed together as closely as possible

If this method is adopted it will be necessary to put the limb up in plaster of Paris as the final stage thus preserving the impaction This operation which is only feasible in a bone like the humerus or

femur that has no companion bone to hold it, is open to the grave disadvantage of producing considerable shortening, on the other hand, it is comparatively easy

Step-cut operation.—This is suitable for an ununited fracture of the humerus or of both bones of the forearm, provided that there has not already been so much loss of substance as to render further shortening inadmissible Preliminary removal of scar tissue and refreshing of the bone ends having been performed, each fragment is brought out into the wound and divided by a longitudinal saw cut for about 1½ in This saw cut need not be quite in the centre of the bone, but should separate off about one third of the thickness from the remaining two thirds The thinner portion, which should be on the inner side of one fragment and on the outer side of the other, is removed, and the fragments are then fitted together, clamped in position and united by two transfixing bolts (Fig 147) In the

Fig 148 —Bolted plate supplementing step cut operation for old fracture of femur

femur additional strength and security may be afforded by placing a 3-in or 4 in plate on one side of the step-cut junction and fixing this to the bone by four bolts, two of which traverse both fragments through the step cut, while one fixes the plate to each main fragment above and below (Fig 148)

Double-cone operation.—This method aims at so shaping the two fragments that one becomes impacted in the other It may be done by hollowing out one end with a gouge while the other end is roughly pointed by a chisel and file More precise fitting may be made by the use of a butterfly reamer This instrument has a peg, $\frac{7}{16}$ in thick, which fits into the marrow cavity of either end, and two outstanding wings set at an angle of 90° to one another and provided with cutting edges The reamer is fitted into a handle or brace and is applied to each fragment in turn one fragment being cut by the converging edges of the tool and the other by the diverging edges In this way one fragment is shaped like the outside of a cone and the other like the inside and these two surfaces fit one another When the fragments have thus been shaped and fitted together, they may be sutured by passing two wire sutures from side to side through each and joining the projecting ends of the wire together, twisting and tightening them firmly

This operation does not produce so much shortening of the bones as those previously described It is suitable for cases of recent injury in which the bones are comparatively healthy A more rigid and permanent fixation may be obtained by an intramedullary peg instead

of a wire suture A bone-peg, 3 in long and $\frac{7}{16}$ in wide, is placed in one fragment after the shaping has been done, and the other fragment is adjusted over its end While the two fragments are closely pressed together, a transverse hole, $\frac{1}{8}$ in in diameter, is made through each and through the central peg, and into these holes bone nails are driven

Bone Grafting

The ideal method of dealing with an ununited fracture is the insertion of a bone graft New bone tissue is introduced in the area of the ununited fracture and will serve (1) as a conducting bridge, across which new bone can cross from one fragment to the other (2) as a strut which holds the fractured ends together and (3) as a source of new bone reparative tissue The graft may be attached to the fracture as a cortical inlay, a groove being cut in both fragments and the graft shaped so as to fit into this groove, or it may take the form of an intramedullary peg, driven up into one fragment and fitted into the other by splitting the shaft The details of these operations are given below If the ununited fracture is in a bone of good substance, and if the fragments can be brought into contact with one another so that no gap exists, then the bone used for grafting may be dead animal bone in the form of plates or pegs prepared and sterilized beforehand

Indications —The main indication for bone-grafting is the loss of a portion of the skeletal structure either by injury or disease There are four typical conditions which may require bone-grafting —

1 **Ununited fractures** —In these conditions there may be no loss of bone, and the main fragments, after removal of the intermediate scar tissue, can be brought into contact

2 **Loss of substance caused by injury** —This is usually due to a gunshot or other form of compound fracture The loss of bone may have been caused by the original injury, by operative removal of bone fragments, or by septic processes in the wound The gap may be maintained to some extent by an uninjured companion bone, or by deliberate traction In these circumstances the remaining portions of the shaft become much atrophied—that is, they are reduced to thin shells of bone by an absorption of the solid substance and an enlargement of the marrow cavity The gap itself is usually filled with a very dense mass of scar tissue In a bone like the femur, where there is nothing to maintain the gap the bone fragments become approximated until a condition of fibrous union or false joint (p 270) is present The bone ends instead of being atrophied, are then often thickened and sclerosed

3 **Loss of bone resulting from osteomyelitis** —This usually is a loss of the diaphysis, totally or in part, the result of surgical removal with the idea of cutting short the disease The epiphyses remain, with the epiphysial cartilages and there is nearly always a ragged portion of the shaft at each end The gap from which the bone has

been lost will usually be occupied by a certain amount of scar tissue remaining from the original inflammatory disease and it is covered by skin which is puckered by an adherent scar The limb is frequently deformed by the uncontrolled growth of a companion bone For example if the tibial diaphysis has been lost the fibula by its growth will have produced external bowing of the leg and inversion of the foot

4 **New growths of bone**—Malignant tumours of bone whether primary or secondary sarcoma or carcinoma usually require amputation of the limb but there are certain non malignant tumours and cysts which justify the more conservative treatment by local excision Such an excision should always be followed by a bone-grafting operation to fill the gap This condition affords the most favourable circumstances for bone grafting because all the tissues are healthy and there is no scar tissue latent sepsis nor deformity to deal with and the grafting can usually be carried out at the same time as the removal of the tumour or cyst

General principles—Bone has a low grade of vitality and very limited power of growth The adult bone contains a very large proportion of inert earthy salts and a very small proportion of blood vessels and living cells When a graft is placed in a gap in one of the long bones it is capable of acting in three ways (1) It forms an internal splint or strut which restores skeletal continuity (2) it acts as a conducting medium into and around which new bone cells and blood vessels grow from the neighbouring host bone (3) possibly a few of the living cells of the graft survive and help to form new bone

Matti's operation—Hitherto all evidence has pointed to the death of transplanted bone followed by penetration and regeneration by new bone cells from the host bone But Professor Matti has shown that if spongy bone is used it actually survives with re ossification The bone is exposed by a simple incision directly over the ununited fracture and the skin muscles and periosteum are raised in one layer The front surface of the sclerosed bone is freely cut away until the marrow cavity is exposed and until at each end of the bone cavity freely bleeding bone is reached The exposed marrow cavity is scraped out with a sharp spoon All fibrous tissue intervening between the fractured surfaces is cut away except at one point where enough is left to act as a fixation agent An opening about the size of a shilling is made over the great trochanter and about two dessert spoonsful of red spongiosa are scraped out together with blood and fat All this is now pressed into the gutter shaped cavity and between the bone-ends of the fracture The previously removed cortical bone is chopped up into fragments about the size of grains of rice and packed loosely on top of the spongiosa transplant The mass is held in place by suturing the muscles and skin over it A stab drain should be used to prevent a hæmatoma The limb is laid on a splint (Braun's splint for leg pillow or Cramer wire for arm) for 10 to 14 days after which a cast is applied

Functions of the ordinary bone-graft.—The essential element in the "taking" of the ordinary bone graft is that, whilst its own cells die and its vascular canals become empty, these are rapidly penetrated by vascular tissue from the host-bone and from the surrounding tissues. The autogenous graft is much more readily penetrated than is a piece of dead bone and this probably constitutes its chief superiority. The three functions of the graft, viz. those of the strut and the osteo-conductive and osteo-productive functions are carried out simultaneously and are all favoured by the same circumstances—firm fixation to and wide contact with the host-bone. Moreover there is evidence that the functions of forming new bone and of acting as a scaffold for the ingrowth of bone from the host are favoured and stimulated by the mechanical fixation which transmits stress and strain to the newly constituted bone. A bone graft will not grow in size at all until it has become an integral unit in the skeleton. On the other hand, from the moment of its implantation it will be subjected to the disintegrating and absorptive influences of the leucocytes of the surrounding tissues. It follows, therefore, that while a bone graft will always be liable to absorption, it will not undergo growth except under favourable conditions. Where practicable, the graft should be cut not merely of the full size, but rather larger than the portion of bone which it is intended to replace. The bed in which it is implanted should be free from all scar and consist of healthy vascular tissue. Above all, the graft should have as wide a contact with fresh surfaces of the host bone as possible, and it should be fixed to the latter so firmly that movement between the two is impossible.

Source of the bone-graft.—There are three possible sources from which bone-grafts may be obtained—animal bones, dead bodies or amputated human limbs, or the patient himself. Animal bones may be of various kinds. Ivory is particularly suitable for grafts which are likely to be subjected to great strain—for example, the femur—and also for small pegs or nails; beef bone is easily obtained from the shin-bone of cattle and is conveniently prepared in strips of various shapes and sizes, but, while capable of providing almost any length, it can only with difficulty be obtained thicker than ⅜ in., and is not suitable, therefore, for stout round pegs. Stags antlers provide the best source for thick round pegs; the bone of which they consist is solid, homogeneous, and of a more open texture than the cortex of tubular bones. "Os novum" is made by sterilizing and defatting prepared pieces of beef bone; it is conveniently prepared in pieces of all sizes and shapes.

Homogeneous grafts taken from human tissues recently dead or amputated are of theoretical rather than practical interest. They have been used principally for the replacement of the articular ends of bones lost by injury or disease, but the difficulties of securing the material when it is wanted and of getting it free from disease or sepsis, are too great to make it generally useful.

Autogenous grafts from the patient's own bone tissue are of the greatest general utility They not only serve as a strut and as osteoconductive material, but also exhibit spontaneous vitality, as is shown by callus-production when the graft is fractured Four bones have been commonly used The *shaft of the tibia* is extremely useful, being long, strong and very convenient of access From it a graft 10 in long, $\frac{3}{4}$ in broad, and $\frac{1}{2}$ in thick may be cut The *fibula* is long, and can be used for the upper three fourths of its extent It is more difficult of access than the tibia and a graft cut from it is not so strong as one from the tibia The indications for its use are very limited being practically confined to the replacement of the upper end of the humerus for which the head of the fibula forms a good substitute The *ribs* were frequently used at one time for grafting operations, but they have very little to recommend them, as they appear to be especially liable to rapid absorption The curve of the rib suggests it to replace a curved bone such as the lower jaw, but for this purpose it is inferior to the crest of the *ilium*, the fourth common source of autogenous grafts The ilium has been used for a solid curved graft to fill a gap in the lower jaw, and for small chips to fill a gap in a long bone or to supplement some other method of grafting

Preliminary treatment.—All cases in which the loss of bone has been associated with septic inflammation, whether cases of osteomyelitis or of gunshot wound, require very careful preliminary treatment It is necessary to remove, as far as possible, all scar tissue, together with the material in which latent infection still lurks

In the first place, sufficient time must be allowed to elapse between the healing of the original wound and the operation at least three months, and usually much longer

The general health, especially in regard to anæmia secondary to hæmorrhage or infection, must be normal Even when local and general conditions are satisfactory, it is wise to give both massage and ultra violet light, to increase resistance and to provoke a local reaction This may lead to a "flare up," but this is better before than after a grafting operation

Any tight puckered or adherent scar in the skin near the site of the operation will endanger success Such scars must be carefully removed and the deep fascia, subcutaneous fat, and skin sewn up in separate layers without tension If a free excision of the cutaneous scar leaves a gap which cannot be closed without tension, this gap should be made good by means of a pedicled flap of skin and fat taken from another part of the body In the upper limb, the flap is easily fashioned from the loose tissue covering the chest, while in the lower limb it must be taken from the opposite leg, or by turning down a piece of skin from the same leg by successive reversals, the so-called "somersault flap" (*See* section on Plastic Surgery, Vol II) In either case the flap operation is done in two stages, a wide pedicle being allowed to remain for ten days after the first stage, and divided at the second

The removal of the deep scar tissue together with any debris of foreign bodies which may lie in the tissues may be done at the same time as the cutaneous scar is being replaced or may be postponed to form the first stage of the bone grafting operation Probably the former is the better Portions of this deep scar tissue may be cultivated to ascertain the presence and nature of infective organisms From such a culture suitable vaccines should be prepared and administered

As far as possible any marked deformity should be corrected before the bone grafting operation For example in a gap fracture of the radius the hand lies fully pronated and adducted to the radial side Both these deformities can be corrected to a large extent by forcible manipulation and traction under an anæsthetic and such correction maintained by a plaster of Paris dressing

Thus the preliminary treatment may involve a series of procedures occupying a year or more

Instruments required —In addition to the bone set (p 288) it is necessary to have a special saw for cutting the graft *Albee s motor driven pattern* being the best In the more complicated operations appliances will be necessary for shaping and fitting the graft and the host bone viz a set of twist-drills and handle a dowelling or reaming plate metal templets files and a small vice attached to a separate table for holding the graft while it is being shaped There has been some difference of opinion on the best instrument for cutting the graft It is contended that the rapid action of a motor-driven saw tends to kill the bone cells by heat and to choke the pores of the bone with dust But practical experience and observation show no difference in the behaviour of grafts whether cut by motor saw or by chisel The appliances for cutting the graft by chisel should always be to hand in case the electric instrument should fail

Technique —The details of a bone graft operation vary very much and for the sake of simplicity it will be best to describe several typical operations The first stage in all cases is however essentially the same exposure of the area to be grafted and removal of all the scar tissue from the future bed of the graft together with an excision of the ends of the host bone For a gap left by osteomyelitis or a fracture *this important stage may be long and tedious as the removal of all* scar tissue is important in order to get rid of a source of latent sepsis and to provide a healthy bed for the graft The corresponding stage in local tumour or cyst is much easier and consists in a subperiosteal resection of the affected portion of the bone The end of this stage leaves a trough in the soft parts between the cut ends of the host bone The bone grafting operation fills this gap or trough but does so in a number of different ways which differ chiefly in the method by which the graft is attached to the host bone

Bone chips —This is the easiest but least successful of all methods It very seldom effects a firm or solid union in an adult bone it should therefore never be employed except as an adjunct to more efficient methods or when other methods are not available

A piece of bone is taken, usually from the crest of the ilium, of a size sufficient to fill the gap An incision is made along the outer lip of the iliac crest for about 6 in, and the muscles attached to the bone are separated by a rugine The bone required may then be cut off with a saw or removed with a chisel, and the tissue replaced and sutured over the ilium The bone removed is divided up into small pieces about ¼ to ⅛ in thick by bone cutting forceps The pieces so formed are then packed as closely as possible into the gap and the soft parts are sewn over them so as to enclose them in a tube continuous at each end with the host-bone No rigidity is obtained by this method and it is therefore necessary to put up the limb in a plaster case As a rule bone-chips thus transplanted survive for a considerable time, and form a feeble bond of union between the ends of the host bone But there is no real restoration of continuity, force cannot be transmitted across the gap, and at the end of six or twelve months the X-rays fail to detect anything but a faint shadow of the grafted chips

Bone-chips may also be used as a supplement to some other method —that is to say, when a solid graft has been laid into the gap, bone-chips may be strewn over the points of junction between the graft and the host-bone Used in this way, the chips will probably contribute somewhat to the junction between the bones, but the value of this contribution is somewhat doubtful

Massive graft —This is the operation by which the greater part of the diaphysis of a bone is made good

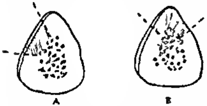


Fig 149 —Two methods of cutting graft.

The graft should be cut from the shaft of the tibia, and should be about 2 in longer than the gap it is intended to fill A curved incision is made on the outer side of the leg, beginning at the tubercle of the tibia, and ending in front of the ankle The flap thus formed is turned inwards until the medial surface of the tibia is fully exposed The muscles are separated from the lateral aspect of the bone The periosteum is divided near and parallel with the inner margin of the tibia, and about ⅛ in behind and parallel to the crest The bone is divided by four saw-cuts the two longitudinal cuts running down the middle of the medial surface of the bone and about ⅛ in behind the crest, while the transverse cuts join the end of the longitudinal ones This produces a flat but rather thin graft (Fig 149A) If a stronger graft is required then one longitudinal cut goes down the middle of the medial surface while another goes down the lateral surface about ⅛ in behind the crest This graft will include the crest and is of great strength (Fig 149B) In making these cuts with a motor-saw, cold saline solution should be run on to the bone at the point of section, the surgeon either using a special irrigator, or dripping the fluid on to the saw by means

of a swab The soft parts should be carefully protected by adequate retraction In making the transverse saw cuts care should be taken not to go beyond the depth required because a transverse cut going deeply into the shaft of the bone is very apt to lead to subsequent fracture When the four cuts have been made the graft is separated from the bone by a few light strokes with a chisel special care being taken to prevent the graft from springing off and falling on the ground The wound in the leg is closed by suture of the skin flap with inter

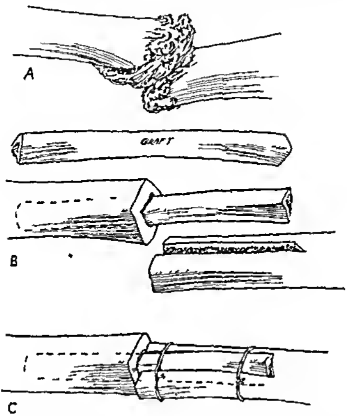


Fig 150 —Massive graft of femur

A ununited fracture of femur B 8 in graft cut from tibia of same limb gutter cut in lower fragment of femur upper fragment drilled and graft buried for 4 in in upper fragment C, operation completed graft uniting tendon having been placed in gutter and secured by two kangaroo tendons

rupted silkworm gut stitches The graft is then fitted into place, by thrusting one end into the smaller fragment of the host bone, while the other is made to occupy a slot cut in the larger end (Fig 150) Strong traction should be made on the limb while the graft is hammered into place so that the tension of the soft part may hold it firmly in position It may be necessary to fix this part of the graft in position with encircling ligatures of strong catgut, kangaroo tendon or wire as shown in Figs 150 and 158 The muscles and fascia are sewn together over the graft in order to bury it as deeply as possible below the skin The skin having been sutured with catgut, the limb is put up in plaster of Paris

which remains in position for two or three months being taken off and renewed if necessary during this period

Cortical inlay graft—This operation may be used for an ununited fracture without a gap or for a gap fracture where the interval to be filled is not large It is particularly useful in repairing defects of the *tibia* and it will be described for that bone

The bed for the graft is prepared as follows The preliminary stages for scar excision are first done and the bone is then held in the position which it is intended finally to assume and is temporarily fixed by nailing on to its surface an aluminium templet $\frac{3}{4}$ in wide and 6 in long after the periosteum covering the bone has been reflected (Fig 151) The cortical layer of the bone is then cut through by means of a motor saw which is applied close to the edges of the templet The longitudinal cuts should be in planes which converge towards the centre

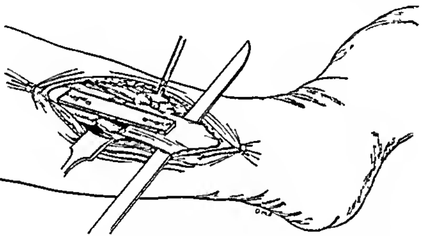


Fig 151—Cutting gutter in ununited fracture of tibia in preparation for graft.

of the bone and the cross-cuts should undercut the bone so that the deep surface of the pieces of bone removed is longer than the superficial The templet is now taken off and the pieces of bone marked out by the four saw-cuts are removed by a chisel They should be preserved and used for wedging into that part of the gap which lies deep to the cortical graft The graft is now cut from the other leg (Fig 152) The tibia is exposed by a curved flap incision A second metal templet $\frac{1}{16}$ in wider and longer than that used for cutting the bed is fixed to the bone serving to mark out the portion of bone to be removed and at the same time to protect the periosteum The saw cuts surrounding the graft should be similar in direction to those made in cutting the bed—that is to say the longitudinal cuts should be in converging planes and the transverse cuts in diverging planes It will be necessary to make an extra cut at one end beyond the graft with a saw or chisel to release the undercut end of the graft

The parallel cuts for the graft and its bed can be made by twin saws

This saves all the preparation and use of the templets, but it is necessary to adjust the distance of the twin blades very carefully so that they are $\frac{1}{8}$ in wider apart *when cutting the graft than* when cutting the bed This is to allow for the thickness of the saw blades Furthermore the twin saw can only make vertical cuts, whereas the single saw can make converging cuts so as to form a wedge shaped transverse section to the graft

The graft is taken out and the wound closed in that leg The graft, still protected by the templet, is now placed in the slot prepared for it, being hammered down into position, and the ends being held by the overhanging edges made by the end saw cut At the actual moment of insertion the fragments of the host-bone are pulled apart from one another, so as to allow the ends of the graft to fit into place The

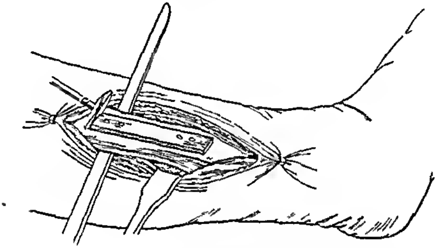


Fig 152 —Cutting graft from tibia.

templet is removed and, if the fitting has been accurate, the graft will be firmly held This inlay graft only bridges a portion of the thickness of the bone, the remainder of the gap should be filled with the pieces cut out from the host bone in making the bed These pieces should be cut into short lengths exactly fitting the gap, and placed side by side Further security of fixation may be afforded to the graft by making several holes obliquely outwards at the margin of the graft and its bed, and filling these with tightly driven bone nails The soft parts are brought together as closely as possible, and the skin-flap sutured in place The limb is put up in plaster as before

"Cricket-bail graft."—In dealing with a gap fracture of one of the tubular bones, such as the radius or humerus, it is desirable to place the graft in the axis of the bone, because it is only in this position that the graft can truly restore continuity to the shaft, and also because the ends of the host-bone are usually so thinned by atrophy as to present mere tubular shells If such a shell has a part cut out from its wall, it will collapse, whereas if a plug is driven into its interior,

it will be greatly strengthened This operation is done for example when in the middle of the shaft of the *radius* there is a gap which after the unhealthy ends have been removed and the arm pulled out to its maximum length is 2 in in length

A graft is cut from the crest of the tibia 4 in long ¾ in wide and ½ in thick and while the assistant is sewing up the leg from which the graft has been taken the surgeon shapes the two ends of the graft so as to fit into the marrow cavity of the host bone The latter should have been drilled out by twist-drills and accurately gauged for rather more than an inch in each fragment The graft is fixed in the vice with one end pointing upwards One inch of this end is formed into a round peg cutting it down to the approximate size by a saw and file and then shaping it with a dowelling plate the holes in which correspond in size to the twist-drills In the forearm bones this size will usually be $\frac{5}{16}$ or ⅜ in The other end of the graft having been similarly treated a piece of bone is obtained of a shape somewhat resembling that of a cricket bail having a central thick body to which the periosteum is still attached with a peg shaped end In fitting the graft into place one end of the host bone must be split by a longitudinal saw-cut for about 1½ in One end of the graft is driven into the unsplit end of the host bone the other is pressed into the split end after prising the latter open When the graft is in place the split end is secured by a surrounding band of kangaroo tendon or better by a double wire loop Instead of splitting the upper host bone it may be more convenient to cut a bed for the graft as shown in Fig 153 The wound is closed and the limb put up in plaster as in the preceding operations When the grafting is done on the radius the forearm should be put up flexed at the elbow in nearly full supination with the wrist dorsiflexed

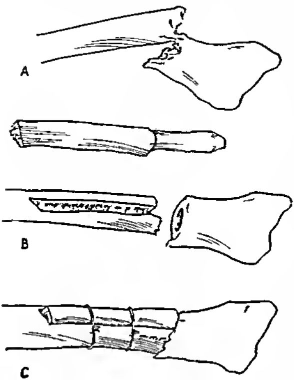


Fig 153 —Inlay graft of radius with intramedullary fixation

A, Malunited fracture of radius B graft cut from tibia and fragments of radius prepared to receive C operation completed.

Inlay combined with intramedullary fixation —It is sometimes incon

venient, particularly in the *humerus*, to place both ends of the graft in the marrow cavity of the host-bone on account of the difficulty of splitting the shaft, or because, the shaft having been broken obliquely, it has a long projecting spike in which there is no central canal. In these circumstances it is better to use a combination of the two foregoing methods. This combined operation will be made clear by describing it as done for a gap below the surgical neck of the humerus.

The fracture is first exposed by an incision along the anterior margin of the deltoid muscle, and all scar tissue removed; the upper fragment then has its end grasped by a forceps and is tilted out into the wound. A hole is drilled in its axis for the full length of the fragment, and about $\frac{7}{16}$ in. in diameter. The shaft of the bone is next exposed by prolonging the incision, and a portion of the cortex is removed so as to make a groove about 4 in. long and $\frac{5}{8}$ in. wide. The graft is then cut from the crest of the tibia, its length being equal to the combined lengths of the groove in the shaft, the gap in the bone, and the tunnel in the upper end. It should be about $\frac{3}{8}$ in. wide and $\frac{1}{4}$ in. thick. One end is shaped as a peg $\frac{1}{2}$ in. thick, and the other end is shaped to fit the groove in the shaft. The peg is driven into the head of the humerus, while the other end, being laid into the groove prepared for it, is clamped there by forceps and fixed in position by two double wire loops.

After the wound has been closed and a dressing applied, the arm is supported on an internal angular splint reaching well up into the axilla and down to the palm of the hand. When the patient is in bed the arm on the splint should be slung up to an overhead beam and not allowed to hang down. At the end of a week or ten days a plaster jacket is applied, surrounding the chest and arm, and keeping the latter in abduction at the shoulder, flexion at the elbow, and dorsiflexion at the wrist, the hand being brought opposite the patient's chin. This plan of delaying the application of plaster has two advantages: the plaster will not become soiled with blood, and it can be applied with greater accuracy and comfort when the patient is sitting up and conscious than if it is put on at the time of operation, when he is lying on his back.

The two-piece intramedullary graft.—This method is specially designed to fill a gap in the shaft of one of the long bones, when it is desirable not to shorten the bone, and when the maximum of strength is required. Such conditions are most often found in the *humerus*, when a part of the middle of a shaft has been lost by injury or removed for disease. In the latter case, particularly in young patients when it has been possible to resect the disease without removing the periosteum, the graft may be made of beef bone; but when the gap is due to injury and resulting sepsis, it must be filled by living bone.

The first stages of the operation consist in the exposure of the defect, the removal of scar tissue, cutting off the ends of the bone, and drilling the bone with twist-drills up to about $\frac{3}{8}$ or $\frac{7}{16}$ in. in thickness, for a distance of 2 in. into the medulla of each portion of the remaining shaft. Supposing the gap to be filled measures 2 in., it will be necessary

to cut a tibial graft 8 in long, $\frac{3}{4}$ in wide, and as thick as possible The periosteum should be preserved on the graft in its middle four inches The graft is then cut into two pieces, each 4 in long, and each with one end shaped as a peg $\frac{7}{16}$ in thick and 2 in long (Fig 154) The big ends of each piece are smoothed and flattened on their deep surface, so as to fit against one another Each piece is then driven into one fragment of the host bone, and the projecting ends of the two grafts are clamped together and fixed by two small bolts and nuts The effect of this arrangement will be that the gap in the bone is filled by a double thickness of graft, making a mass $\frac{3}{4}$ in wide and 1 in thick The arm should be placed on an abduction splint, and later put up in an abduction plaster, as described in the preceding operation

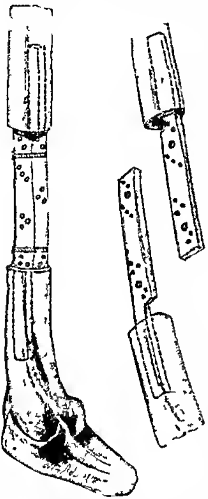


Fig 154—Humerus with two piece graft in position bolted together

The holes in the graft are made to promote penetration by new granulation tissue

Two-piece inlay graft—Here the special object is to secure the greatest possible strength for the bony union This method is chiefly indicated for gap fractures or non-union of the *femur*, and it can only be done for a bone of firm, strong substance

Technique—The shaft of the femur having been widely exposed and the soft parts drawn aside, the ends of the bone are refreshed and brought into contact A shallow groove is then cut on each side of the bone about 4 in long and $\frac{3}{4}$ in wide This may be done by a templet and motor-saw, or by simple chiselling In either case, the groove should be only sufficiently deep to give a flat surface on either side of the tubular bone The graft is then cut from the tibia in the usual way, being 8 in long, $\frac{3}{4}$ in wide, and $\frac{1}{4}$ in thick, and the periosteum being taken for its entire extent It is cut into two lengths of 4 in, and each of these is smoothed on its deep surface The two grafts are then placed one on each side of the femur, in the grooves prepared for them, and, when the fitting has been adjusted, are clamped in position and fixed by means of bolts and nuts (Fig 155)

A modification of this method consists in using a steel plate on one side of the bone and a graft on the other, to add to the rigid strength

of the junction Such a modification however while adding to the immediate strength will not give so strong a bone in the end

Bone graft used as a nail —The operation of nailing a fracture of the neck of the femur by means of a bone nail or bone graft has already been mentioned (p 244) It is not necessary to give further details

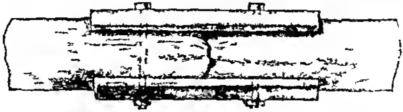


Fig 155 Double cortical graft fixed by bolts

but the indications for its performance elsewhere are in general the existence of an ununited fracture of one of the long bones near its articular extremity so situated that a graft can be readily driven from the end of the bone into the shaft In each case it will be necessary to expose the site of fracture and remove fibrous and scar tissue from between the bone-ends and to refresh the surfaces The bone-nail may be dead or living material but although the former may be equal to its task the latter should always be used when possible for the sake of the vital element

The head of the humerus may thus be fixed to the shaft for a fracture in the anatomical or the surgical neck (Fig 156) For this purpose it will be necessary to open the shoulder joint to gain access for the graft The hole in the head of the humerus should be made from below upwards the cartilage covering its surface being reflected as a flap

The lower end of the humerus may be nailed to the shaft in a similar manner but it is not necessary to open the elbow joint *If this has been fixed by ankylosis* the lower fragment of the humerus may be drilled straight down until the drill end emerges through the olecranon If the joint is normal it should be acutely flexed and the drill driven downwards to emerge through the olecranon fossa and the tendon of the triceps

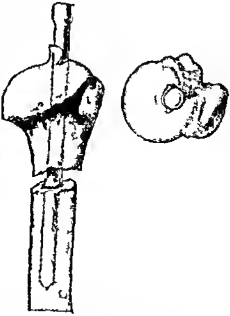


Fig 156 —Method of nailing ununited fracture of neck of humerus Figure on right shows flap of cartilage marked out

The upper end of the ulna may be similarly nailed to the shaft

for an ununited fracture the head of the nail being buried in the insertion of the triceps (Fig 157)

At the upper end of the femur the nailed graft may be used to fix either a fracture of the neck or a fracture of the shaft at the level of the small trochanter

Lastly the method is well suited for cases of fracture of the posterior process of the os calcis

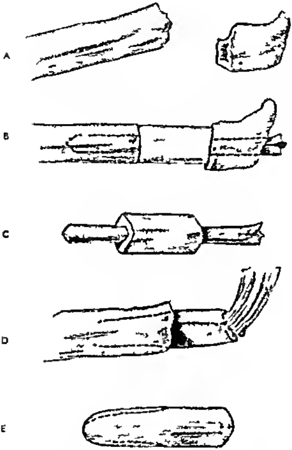


Fig 157—Different methods of restoring fractured olecranon after non union

A gap f acture B united over autogenous peg cut in the shape of C D end of olecranon replaced by graft shaped as in E the triceps tendon being fixed to end of graft chromic gut s tures perforating the bone

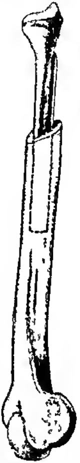


Fig 158—Reconstruction of upper third of humerus

Head of fibula is fixed in shaft of humerus by means of wedge cut from fibula

Terminal graft to replace the articular end of a long bone—In cases in which the articular end of one of the long bones has been destroyed by injury or removed for disease it may be possible to substitute for it the upper end of the fibula This operation has generally been done for loss of the head of the humerus but it is also

suitable in substitution for the lower end of the radius or possibly for the head and neck of the femur It will be sufficient to describe the operation as done for loss of the *head of the humerus*

First the region of the shoulder joint is exposed by an incision running vertically downwards from the tip of the coracoid process between the deltoid and pectoral muscles as far as the insertion of the former If the case is one of disease such as myeloma the involved portion of the bone including the head is resected after stripping off the insertions of the muscles attached to it If the case is one of old gun shot injury the scar tissue is carefully dissected out from the soft parts and the end of the shaft cut off by a transverse section The wound is temporarily packed while the graft is being cut

An incision is made over the outer aspect of the fibula of sufficient length to remove the required part of the bone allowing for at least 2 in to be driven down into the shaft of the humerus and a further inch for a wedge The head of the fibula being exposed the attachments of the external lateral ligament of the knee joint and the biceps tendon are separated from it This is best done by chipping off the portion of bone to which these structures are attached this piece being subsequently fixed to the external tuberosity of the tibia by a short nail

The point which next requires attention is the *preservation* of the external popliteal nerve which should be drawn forwards in front of the bone The muscles arising from the shaft of the fibula are separated from the bone by a sharp rugine The bone is divided at the selected spot by means of an Adams saw and the upper portion removed after separating deep muscle fibres from it with a due regard to the integrity of the branches of the external popliteal nerve The size of the shaft of the fibula varies a good deal and it will probably happen that the lower end is smaller than the cavity of the humerus which it is destined to fill In these circumstances the lower inch of the fibula should be cut off split in two and fashioned into wedges The fibula is driven for 2 in into the shaft of the humerus (Fig 158) and if it does not fit tightly the wedge already prepared should be driven in between the junction of humerus and fibula The soft parts in which the graft now lies should be sewn over it with an endeavour to restore as far as possible the natural relations of the upper end of the humerus

Accidents and complications in grafting—It sometimes happens that the graft when cut falls on the floor What is to be done? If the graft is small then another should be cut but if it is a massive graft which cannot be duplicated then it should be thoroughly washed in sterile water followed by spirit Or it may be boiled for one minute and then washed in spirit

Sepsis may follow a bone graft operation Acute septic infection within a few days of operation will demand free opening of the tissues and probably removal of the graft But late and mild septic phenomena a mere sinus occurring after union of the greater part of the wound is complete is a different matter In these circumstances the utmost conservation and patience should be exercised If the sinus

does not give the needed drainage, it should be enlarged and the cavity with the graft at the bottom should be swabbed out with spirit and dressed with vaseline or Bipp Even if the graft does not live and has eventually to be removed, it may act as a strut and as a bridge along which new bone grows, or a part of the graft may grow in its place and a part be thrown off as a sequestrum

Bone Substitution

It sometimes happens—especially in the forearm—that an important bone has been partly destroyed and that its place may be made good by an adjacent bone A part of the shaft of the radius may have been

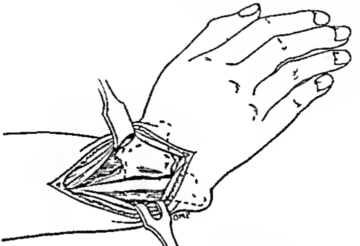


Fig 159 —Substitution of ulna for radius

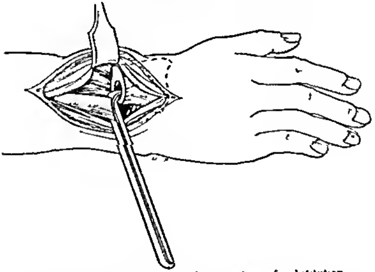


Fig 160 —A further stage in the operation of substitution.

lost as the result of a gunshot wound, osteomyelitis or new growth If the lower end of the radius is intact, then the ulna may be cut through at its lower end and thrust into the lower end of the radius

Instruments required.—The usual "bone-set" together with a grooved director, with a beaked end to act like a shoe-horn. This can easily be made by bending a piece of iron plate.

A short incision is made over the medial border of the lower end of the ulna and the lower end of the bone is cut from the shaft by a fine saw. (Fig. 159.) A second incision is made over the lateral border of the lower end of the radius and the ragged surface of the bone is exposed and refreshed by a fresh saw-cut, and with a twist-drill a hole is made in it of a size which will admit the cut shaft of the ulna. The shaft of the ulna is then pulled into the axis of the forearm and

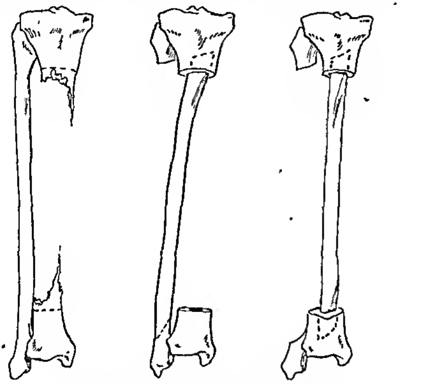


Fig. 161.—Restoration of tibia, using fibula.

impacted into the lower end of the radius. (Fig. 160.) The wounds having been sutured, the arm is put up in plaster of Paris, with the elbow at a right angle and the hand in three-quarter pronation.

A similar but more difficult operation may be done to substitute the shaft of the tibia by that of the fibula. It will have to be done in two stages. In the first, the upper part of the fibular shaft is divided and implanted into the tibia, great care being taken of the lateral popliteal nerve. A month later, the lower end of the fibular shaft is divided and implanted into the lower end of the tibia. (Fig. 161.)

Bone-grafting for Spinal Caries

Tuberculous disease of the spine usually attacks the bodies of the vertebræ. Both the pain and the deformity associated with this disease

are due to pressure forcing the vertebral bodies together Each vertebra, if viewed sideways represents a lever the fulcrum of which is at the articular process about midway between the front and the back of the bone while the body in front and the spinous process behind constitute two arms of the lever (Fig 162) If the condition of three adjacent vertebræ be considered the mechanics of this disease and its operative treatment will be clear Suppose the middle vertebra to be the site of tuberculous caries the weight of the upper vertebral body will be transmitted through the middle one to the lower but as the middle vertebra becomes softened and destroyed it collapses as the result of this pressure weight and the body of the upper vertebra will fall down upon that of the lower hingeing upon the articular processes and opening up the spinous processes behind The collapse of the vertebral bodies upon one another and the pain caused by this process will be prevented if the tips of the spinous processes are tied together so that they cannot be moved apart Moreover this fixation of the vertebræ to one another will produce a condition of rest very favourable to the healing of tuberculous disease Efforts to bring about this fixation have been made by various devices (1) Metal bands and wires have been introduced to tie the bones together (2) the spinous processes themselves have been broken or cut in different ways so that they may fuse with one another and (3) a living bone graft taken from another part of the body has been introduced to bring about ankylosis of the spine It is only necessary to describe the second and third of these operations

Fig 162 —To illustrate principle of spinal fixation operations

Apart from operation tuberculous disease of the spine requires so much time and patience for its treatment that the prospect of any shorter way to a cure will always be welcome It is by no means certain to what extent these operations do shorten the treatment of spinal caries In a large number of cases in which the operation has been done with apparent success it has been necessary nevertheless to keep the child recumbent for one or more years afterwards It is probable therefore that this operative treatment will not take the place of conservative measures in children if a suitable sanatorium is available In children treated in city hospitals operation gives better results than can be obtained by a spinal jacket with out patient supervision But this is due largely to the three months rest in bed which it enforces Probably the main indications for operative fixation are the disease in adults and its localization to a restricted area

Experience has shown that prolonged rest is always an essential

element in the cure of spinal caries, and that fixation operations should not be performed until active disease is at an end. This is recognized by the cessation of local tenderness and of muscle spasm.

An abscess, not otherwise obvious, can usually be recognized by the X-rays. If it is stationary it is probably caseous and can be ignored. If it is spreading and giving rise to pressure signs (weakness and spasm of the legs with increased reflexes), it should be relieved by aspiration or by the removal of one transverse process and the head and neck of a rib (*costo-transversectomy*) followed by blunt opening of the abscess, evacuation and insertion of Bipp.

Hibbs's operation.—The instruments required are those of the bone-set (p. 233).

Technique.—The area of the spine affected is exposed by a slightly curved incision through the skin and subcutaneous tissue. The spinous

Fig. 163.—Hibbs's operation.

Fig. 164.—Modified Hibbs's operation.

processes are cut down on, including at least two above and two below the diseased area. As the latter exposure usually involves at least three vertebræ, the total number of spines exposed will be about seven. By a chisel or sharp rugine the soft tissues and periosteum are separated from all these spinous processes, and also from the laminæ and articular processes, and the muscles retracted from them. Each spine is cut half through near its base, beginning with the lowest in the series. It is then broken downwards; the spine above, treated in the same way, comes to rest with its tip upon the broken surface of the one below. (Fig. 163.) All the spines having been similarly treated, the muscles are sewn closely together and the skin wound closed.

The details of this operation have been a good deal modified by different operators. The modifications consist chiefly in the different ways in which the spinous processes are cut or broken. Probably one of the most useful modifications is this: the tips of all the spinous

processes to be ankylosed having been exposed, they are split into two equal halves by a saw or a fine chisel. The base of one half of each spine is then cut through while the other half is left in place. The separated portions of the spine are twisted so that their cut surfaces lie against the cut surfaces of the fixed portions of the spine, forming a bridge from one to another. (Fig. 164.) In this operation the spinous processes are not separated from the soft tissues surrounding

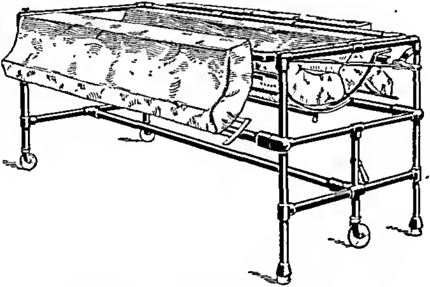


Fig. 165.—Revolving bed-frame for spinal operations: bed open

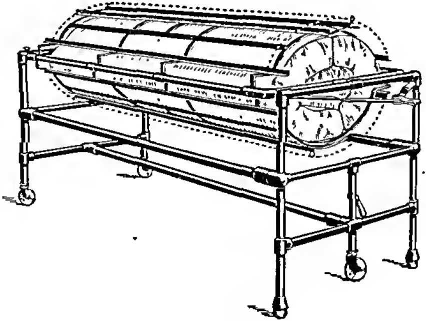


Fig. 166.—Revolving bed-frame: bed closed.

them more than is absolutely necessary They will therefore preserve a better blood supply and undergo repair with greater readiness than if they are widely isolated A further and most valuable detail is that all the *inter articular joints* on both sides of the exposed area should be cut into by the chisel in order to produce ankylosis of each joint

The patient should be kept in bed on a suitable spinal frame or jacket for at least three months, and then, for three to six months more, should wear a well fitting steel support During the whole convalescence, those general measures which so much assist the cure of surgical tuberculosis should be rigorously employed

Albee's spinal graft.—The instruments required are the bone set (p 233) Albee s motor saw a thin bladed chisel and a thick malleable probe for gauging the angle of the deformity

Before an operation for spinal *grafting* is undertaken, a suitable support for after treatment must be prepared This may take the

Fig 167 —Position of patient in bone graft of spine showing how, with body prone the front aspect of the leg is exposed by bending the knee

form of a plaster jacket cut into anterior and posterior halves or the patient may be laid on a padded spinal frame but even in this case an anterior splint moulded to the front of the body will also be necessary for holding the patient when he is turned on to the face for dressing For adults it is of great value to use a special bed which facilitates turning the patient over without twisting or bending the spine (Figs 165 166)

Technique —The patient lies almost prone and a curved incision is made as in Hibbs s operation two spines above and two spines below the affected area are exposed All the spines are split by a fine chisel and one half of each is broken from the base so as to afford an ample gap between it and the remaining fixed portion of the spinous process The size and angle of the groove thus made are gauged by a rod of malleable metal The wound is packed with gauze and temporarily closed while the graft is being cut

The front of the tibia is approached by flexing the patient's knee, and the graft is taken from the leg in this position (Fig 167) If the area of the spine involved by the disease is practically straight, the matter is comparatively easy The difficulty is to get a graft to bridge an angle A slight angulation may be fitted by a curved or angulated graft cut from the internal surface of the tibia But the tibia is not wide enough to permit more than a very open angle being fitted in this way Another device consists in making a number of saw-cuts

In the acute form all the vascular elements of the bone are primarily affected. The infection usually starts in the young bone tissue on the shaft side of the epiphysial cartilage, and thence spreads under the periosteum and into the medulla. It is inaccurate and misleading to distinguish between acute periostitis and acute osteomyelitis, because when the disease is sufficiently advanced to be recognized both periosteum and medulla are always involved, although one may be more affected than the other.

Operation for the Early Stage

In this stage there is a softened and inflamed area of bone in the cancellous tissue next to the epiphysis; an effusion of serum or pus beneath the periosteum raising this from the bone over a small area at one end of the shaft; also an inflammatory process with early suppuration in the corresponding parts of the marrow cavity. At this stage the dense bone lying between the periosteum and the marrow is not affected by any change visible to the naked eye; moreover, in a large bone such as the lower end of the femur the inflammatory focus is usually confined to one portion of the shaft and does not surround it completely.

This early stage may be very transient, particularly in young children and in the smaller bones. But in children over 6, when a large bone such as the lower end of the femur is affected, it lasts several days, and although the diagnosis may be in doubt, it is well worth while to operate without delay, because by timely intervention necrosis of any great extent may be prevented.

Of recent years it has been urged that osteomyelitis should be treated by expectant methods, the limb being kept at absolute rest and nothing being done unless an abscess becomes evident. It is too soon to say whether this is justified by the results.

Instruments required.—Scalpel, two pairs of scissors, six pairs of artery forceps, two pairs of dissecting forceps, probe, sinus forceps, wound retractors, chisel, gouge, hammer, drills of several sizes ($\frac{1}{16}$ and $\frac{1}{4}$ inch), periosteal elevators, needles, ligatures and suture material, drainage-tubes.

Technique.—An incision must be made over the inflamed area of bone, so placed as to avoid injury to the neighbouring joint. At the lower end of the femur it should run up from the most prominent part of the lateral condyle in front of and parallel with the tendon of the biceps. The soft parts are divided or retracted down to the periosteum, which is then incised and the underlying fluid, serum, or pus allowed to escape. The soft parts are now drawn aside and the wound made as dry as possible so as to show the underlying bone. There may be a hole or a soft spot in the cortex leading into the cancellous tissue. If a diseased spot is not obvious there should be no hesitation in making an opening through the cortex by two or three drill holes or the gouge or chisel. A natural opening should be enlarged so that, in either case, free drainage is given to the interior (Fig. 170). The fear that such an opening may lead to an infection of healthy tissues is

groundless, because such infection, even if it has not started in the interior of the bone, will already have been conveyed thither by the vessels which freely connect the periosteum with the marrow tissues at the growing end On the other hand, neglect to make a free opening in the cortex may lead to wide extension of the infective process along the

Fig 170—To illustrate operation for first stage of osteomyelitis after the local abscess under the periosteum has been opened The cortex is opened to give free drainage to the medulla

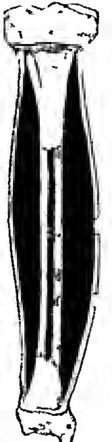


Fig 171—To illustrate operation in second stage of osteomyelitis The periosteum is incised and the dead shaft widely channelled to promote drainage

Fig 172—To illustrate operation for late stage of osteomyelitis Sequestra have been removed and the cavity converted into a shallow trough by removal of about two thirds of its walls

marrow cavity and to consequent necrosis The operation is completed by placing a drainage tube right down into the cavity of the bone and closing the extremities only of the incision, or the vaseline pack may be used (*vide infra*)

Operations for the Second Stage

The early stage of infection is quickly followed by one in which the periosteum is stripped off the shaft for a considerable extent while

the infective process makes a corresponding advance along the marrow cavity This leads to death of the dense shaft of the bone which is bereft of its blood supply both from within and without while the cells in its canals are killed by pressure and toxins In this way nearly the whole of the diaphysis may be killed but a small portion adjacent to the epiphyses at each end usually survives At this stage of the disease one of two operations may be indicated either *simple drainage* or *diaphysectomy*

Drainage is indicated in the larger and more important bones such as the humerus radius femur or tibia and in all cases where the amount of the shaft which is dead is considerably less than the total extent of the diaphysis A suggestion has been made that when extensive death of the diaphysis has occurred the whole shaft should be removed by stripping off the still attached periosteum and wrenching out the bone But this is a dangerous practice and is founded upon a misconception of the functions and capacity of the periosteum It is very likely to lead to a permanent gap with great contraction of the soft parts and no prospect of restitution apart from a bone grafting operation The latter if successful requires a year or more for recovery and then the bone is neither so long nor so strong as the one which has been replaced The new bone by which the diaphysis is replaced is the product of the inflamed bone itself If the latter is removed before it has had time to lay down an involucrum then no bony repair is possible It follows from this that the operation of choice in the second stage of osteomyelitis should be conservative and consist simply of drainage of the periosteal abscess (Fig 171)

Technique —An incision is made over the most prominent part of the inflammatory swelling and when the abscess has been opened is extended in each direction in the length of the bone as far as the structure of the part will allow The shaft of the bone lying in the abscess cavity is smooth and white and as yet there is no demarcation between dead and living bone Where the periosteum is still adherent to the bone it should on no account be disturbed At this stage of the disease there is no separated piece of dead bone but the process of separation may be hastened and the amount of destruction limited if the dead part of the bone is drilled or chiselled so as to open into the marrow cavity A number of holes should be drilled in the dead part of the shaft or a long gutter formed by making two converging cuts in the length of the shaft by a chisel The object aimed at should be to make a funnel shaped cavity with the bone at the bottom With this end in view all overhanging parts should be cut away so as to make the cavity as simple as possible It is swabbed out first with iodine and then with spirit Vaseline gauze is packed into the cavity right up to the surface and the wound left widely open A dressing of vaseline gauze covered by a layer of wool is laid over the limb and the whole is put up in a plaster of Paris cast which takes in the joints above and below the affected bone A careful watch is kept on the

temperature If this settles down to normal within three days the plaster is left undisturbed for 6 or 8 weeks The plaster will become soiled and evil smelling but so long as there is no pain and the temperature remains normal this can be ignored At the end of about 8 weeks the plaster is taken off The pack is removed and the cavity inspected Any loose sequestra are removed and the packing and plaster treatment repeated Frequently after the first change of plaster the wound is found practically healed and only a superficial dressing will be required

The older alternative method of dressing is as follows The funnel shaped cavity having been packed with gauze soaked in antiseptic or in paraffin a dressing and bandage are applied The dressing and packing are changed daily or several times a week This method entails much more work for surgeon and nurse and more suffering for the patient and requires that the patient should be kept in hospital during the whole course of treatment

Diaphysectomy —This operation consists in the removal of the greater part of the diaphysis of an inflamed bone Its performance ought to be postponed until sufficient time has elapsed for an involucrum to form and in bones like the humerus or femur which have no companion bone to support them it should not be done until the involucrum has become strong enough to take the place of the original bone In all cases of doubt it is much better to postpone the operation too long than to undertake it too early It is in bones like the clavicle ulna or fibula that diaphysectomy may be done comparatively early for no ill effects will follow from delayed or faulty regeneration

Instruments required —The same as those mentioned for the early operation (p 295) with the addition of several pairs of sequestrum and bone-cutting forceps and an Adams saw

Technique —The operation may be done as the first attack on a case of osteomyelitis or as a sequel to a simple drainage operation The bone is exposed as fully as possible and the soft parts are retracted from over the centre of the shaft which is then cut through with an Adams saw Each half of the shaft is lifted up into the wound with strong forceps and gently twisted until it separates from the epiphysis The cavity from which the shaft was removed is lightly packed with a Bipp drain and the wound partly closed

This *operation is also suitable for chronic* osteomyelitis due to tuberculosis in children but in this condition no drainage should be employed either as a preliminary or after the removal of the shaft Moreover the greatest care should be taken not to open into the diseased part of the bone but to shell it out from the involucrum

Operation for the Third Stage

The third stage of osteomyelitis is one of repair and *it begins from* the moment when free drainage has been provided for the products of inflammation It consists in two processes—(1) the formation of a

surrounding shell of new bone, the involucrum, which is interposed between the inflamed parts of the shaft and the periosteum, and (2) a separation of the dead parts of the bone from the living The result of these processes is the formation of a sequestrum, which lies in a cavity surrounded by the involucrum lined by granulation tissue, and communicating with the exterior by one or more openings through the involucrum and soft parts, these openings being termed cloacæ

Sequestrotomy.—The operation consists in exposure and removal of the dead bone together with the opening up of the cavity in which it is contained

Technique —The incision is made in the length of the bone and should pass through the sinus or sinuses in the skin At first it is better to use a small incision, enlarging this subsequently in any direction necessary The soft parts should be divided down to the involucrum and separated from it for some extent by a periosteal elevator The cloacal opening in the involucrum is enlarged freely by a chisel until the imprisoned sequestrum can be grasped If the piece of dead bone is too large it should be divided and removed in fragments If the disease has been of comparatively short duration, and if the patient is young, the remaining living bone may be trusted to fill up the cavity This is then treated by a vaseline pack and a plaster case applied as above

Operations for the Fourth Stage

The fourth or last stage in osteomyelitis is merely an exaggeration of the conditions found in the third stage The bone has become enormously thickened whilst, in its interior, various cavities and tunnels exist, containing sequestra which may be large and solid or small and worm-eaten, one or more sinuses open to the exterior This condition may result from ordinary infective osteomyelitis in childhood, when the thickening of the bone affects the greater part of the shaft, or it may be the sequel of a septic fracture, such as that which follows a gunshot injury In the latter case there will be a more or less localized thickening of the bone, while the cavity and sequestra are relatively small The important characteristics of this stage are the permanence of the condition and the impossibility of curing the sinuses unless the cavity is obliterated Two different types of operation may be done In one the cavity is opened up and flattened out by the removal of its superficial walls, in the other the cavity is filled with some foreign material or living tissue

Obliteration of bone cavities. Technique —Supposing the bone involved to be of tubular structure and the cavity to occupy the greater part of its axis, an incision must be made over it which will allow exposure of the whole shaft in its affected portion Such an incision should include the openings of the sinuses The soft parts having been elevated from the bone, the cavity is opened by enlarging the existing cloacæ The walls of the tubular bone are then chiselled

away until rather more than half the circumference of tbe bone bas been removed. The original cavity will now form a sballow trough (Fig. 172), and there is usually no difficulty in making the soft parts lie snugly in this trough, enclosing the wound.

If, however, the thickening of the hone and the cavity it contains are more or less localized to one spot, as usually happens after a septic fracture, it may not be posible to convert the cavity into a groove into whicb the soft parts will naturally drop. In these circumstances it will be necessary to fill up the cavity in some otber way. Several foreign substances have been used for the purpose, such as decalcified bone-chips, pieces of sterilized marine sponge, or various compositions of metal or wax. Such substances, however, are open to tbe grave objection that, unless the cavity to be filled can be rendered aseptic, the operation will be an immediate failure, and, moreover, even if it succeeds at first, infection may occur later from germs latent in the bone, and after a period of months or years tbe wound may break open and the plugging material have to be removed. The same objection, to a lesser extent, applies to the filling of the cavity with pieces of fat taken from the patient's own tissues. By far the most satisfactory filling material is a pedicled flap taken from a neighbouring muscle and turned into the cavity. There is no part of any of the long bones in which this muscle-flap operation cannot be carried out. Thus, in the upper part of the humerus the deltoid will form a suitable flap, in the lower part the triceps; for the femur a piece of the vastus lateralis or crureus will be suitable for the shaft, whilst a piece of one of the heads of the gastrocnemius may be turned up for a cavity in either condyle; the tibia may be filled from tbe tibialis anticus, or in its lower portion with a piece of the soleus.

The first part of the operation is similar to that described above, consisting in the removal by the chisel or nibbling forceps of the outer wall of the cavity The cavity is tben thoroughly scraped, and any irregularities are broken down or recesses opened up, in order to remove the septic material lining the cavity and to avoid recesses wbicb will be difficult to fill. The cavity, having been smoothed out, is firmly packed with gauze, to check the bleeding while tbe muscle-flap is being fashioned. A wide and thick piece of muscle should be taken with a broad pedicle. It is better to use two wide short flaps than to take one whicb is long and narrow. The packing gauze is now removed from the cavity and the flap turned into it. The chief difficulty lies in fixing the end of the flap into the farthest recess of the cavity so as to leave no dead space. To do this, one or two small holes should be made in the depths of the bone, so as to come out on the other side of the limb; through these holes a suture of stout catgut is passed, and by this means the apex of the muscle-flap is anchored in position, the ends of the catgut which emerge on the other side of the limb being tied together over a swab or buried in a separate incision. A few separate catgut stitches will serve to secure the muscle-flaps to the margins of the cavity. The wound should be

closed by a few separate silkworm gut stitches placed sufficiently far apart to allow oozing between them

Sometimes such a wound will heal by first intention but more frequently for the first few days there will be a copious sero purulent discharge which however quickly diminishes and finally disappears in a few weeks

OPERATIONS FOR TUMOURS OF BONE

Benign Surface Tumours

In this group the only tumour of any practical importance is the osteoma which may occur in one of two forms The *ivory* osteoma usually arises from one of the skull bones and is of slow growth and unattended by pain it is important chiefly because of the deformity It should be removed after suitable exposure by a chisel The growth is usually so hard that it cannot be cut and the surgeon should therefore divide the bone from which it grows around its base Another and much commoner form of benign osteoma is the *cancellous* exostosis It may occur as a single bone in an adult in the position of the insertion of a tendon A common example is the rider s bone which is in reality an ossification of a part of the tendon of the adductor magnus Such a growth usually requires no treatment unless it causes pain or irritation by pressure on the skin

The most frequent form of cancellous exostosis consists of multiple outgrowths near the growing end of the long bones in children It appears that each exostosis is formed by an outgrowth from the epiphysial cartilage and for some years each such process has a cap of cartilage at its extremity from which growth continues As the child gets older fresh groups of exostoses may be budded from the epiphysial cartilage while those first formed remain attached to the shaft of the bone at a point which corresponds with the position of the cartilage in earlier years These multiple exostoses are most numerous near the end of the bone where growth is most active—that is at the upper end of the humerus the lower end of the radius and ulna the lower end of the femur and the upper end of the tibia *Usually they are not associated with pain or disability* but their removal may be required for cosmetic reasons or because they interfere with the function of a joint The operation consists in exposure of each exostosis division of the periosteum round its base chiselling through the base of the process and sewing the periosteum together over the raw surface thus formed

Benign Internal Bone Tumours

In this category may be included cysts of bone and myelomata (osteoclastomas) A cyst in one of the long bones is usually first revealed by a spontaneous fracture the underlying cause of which is made evident by the X rays Apart from hydatids which are very

rare in this country, bone cysts are simple and of doubtful origin forming a part of so-called fibro-cystic disease and possibly resulting from parathyroid dysfunction

The treatment of the condition depends on the degree to which the structural continuity of the bone is destroyed If rigidity is not impaired the cyst should be freely opened and the cavity lightly curetted and opened upwards and downwards into the marrow cavity so as to allow cells from the latter to grow into and fill up the gap The wound is closed without drainage If however the continuity of the bone is seriously impaired as evidenced by deformity or fracture and especially when it has to bear considerable stress as in the femur tibia or humerus steps must be taken to reconstitute it If a good shell of bone remains intact then it will be sufficient to fill the cavity left after scraping out the cyst either with an autogenous graft or a piece of dead bone If the continuity of the bone has been destroyed the best method will be a subperiosteal resection of the whole of that part of the shaft which is the seat of the fibro cystic disease together with a fair margin of healthy bone The gap thus formed is filled with a bone graft in the manner already described

Where the strength of the bone has been destroyed it may seem simpler to open the cavity scrape out the lining membrane and break in the walls Regeneration of bone will then take place but this is a much slower process and will require special traction on the limb to prevent shortening and deformity

Myeloma (Osteoclastoma)—This tumour is generally signalized by an expansion of one end of a long bone in a young patient the tumour being surrounded by a very thin shell of bone and the X rays showing a vacuolated appearance The diagnosis should be confirmed by microscopical examination of a fragment from the interior of the growth The treatment should be local removal If the growth occupies only a small part of the bone it can be removed by curetting followed by swabbing the cavity first with pure carbolic acid and then with spirit but it is better if possible to cut out the growth together with a shell of healthy bone This is not often possible without destruction of the continuity of the bone or injury to the joint It may however be done in the lower jaw by cutting out the alveolar margin while sparing the body When the growth occurs in the upper end of the humerus this part of the bone should be resected and replaced by the head of the fibula When it occurs at the lower end of the femur or the upper end of the tibia it will necessitate a reconstructive operation or an amputation unless it is recognized at a very early stage when it can be completely removed without destroying the main bone or opening the joint In the first place the tumour must be removed together with a reasonable margin of healthy bone If this has included the articular cartilage of the femur or the tibia then the knee-joint has to be sacrificed and an attempt made to save the limb without too great loss of length This can usually be done by using a massive graft

from the tibia, which will bridge the gap between the bones and, if the patient is young and vigorous enough, new bone will be formed round this graft to give a strong and serviceable leg

Sarcoma

True sarcomata of bone vary greatly in malignancy Those which originate near the growing ends of the bone in children and young adults pursue such a fulminating course that the most radical operation is of little avail But other varieties, and more particularly those which develop in the site of some traumatic lesion, may be comparatively slow in growth, and there may be no early metastases Sarcomata spread, and also produce secondary growths principally by the blood stream though in certain situations and in certain types, lymph spread also occurs Probably the muscles attached to the bone at the site of disease play some part in dissemination At one time a sarcoma in a bone was thought to require immediate amputation through the joint above the growth, and this treatment was even carried out for myelomata (osteoclastoma) But now it is recognized that, as a routine, this is unsatisfactory In ultra malignant tumours it does too little, for death quickly occurs from secondary deposits In *myelomata* (osteoclastoma) and probably other slow growing tumours as well it does too much, because thorough local removal is sufficient It is not possible to lay down any hard and-fast rule which is applicable to all cases, and each case must be judged on its merits

The conditions which favour local removal without amputation are present when the patient is of adult age, the tumour has a long history, was preceded by a swelling which was the direct result of an injury, such as a hæmatoma, and is in a situation where it can be removed, with the muscles over it, and yet leave a useful limb Tumours growing from the ulna in the upper, or the fibula in the lower, limb fulfil this last condition To some extent, both the X rays and the microscope may assist in deciding that a given tumour is of sufficiently low malignancy to justify conservative treatment, thus, if the X-rays show a large amount of dense bone in the tumour, it is evidence of slow growth and slight malignancy In a portion of the tumour removed for microscopical examination spindle shaped cells, multinuclear giant-cells, fibrous tissue, cartilage and bone are all favourable indications, whilst a tumour composed of round cells like granulation tissue is of bad omen

A sarcoma involving one of the main bones of the limb requires amputation above the joint proximal to the affected bone The outlook after this operation is better in the humerus than in the femur, because in the former the operation consists in removal of the whole forequarter, whereas in the latter it is an amputation through the hip joint

It may be urged in favour of amputation that lasting cure sometimes results, and, further, that it saves the patient from the horrors of ulceration, fungation, hæmorrhage or spontaneous fracture

After amputation, prophylactic injections of Coley's fluid should be given in doses sufficient to cause a sharp febrile reaction

The value of radiation in the treatment of bone sarcoma is as yet uncertain Probably neither radium nor deep X rays have much effect on the primary tumour, but it is possible that either may effect an arrest or delay in the formation of metastatic growths It is wise therefore to use radiation, in either form, after the tumour has been removed, in the hope that recurrence may be prevented

CHAPTER VIII

THORACIC SURGERY

By J. E. H. ROBERTS, O.B.E

In this chapter the operations performed upon the chest will be described as far as possible from the standpoint of the operative procedures rather than from the standpoint of the disease. They will be grouped as follows —

(1) Operations on the respiratory tract and pleura —
- (a) Drainage of acute empyema
- (b) Treatment of chronic empyema
- (c) Drainage of lung abscess
- (d) Removal of intrapulmonary hydatid cysts and foreign bodies
- (e) Major intercostal thoracotomy
- (f) Lobectomy
- (g) Pneumonectomy
- (h) Mediastinotomy and removal of mediastinal tumours

(2) Operations for reducing the size of the thoracic cage, i.e. surgical collapse therapy
- (a) Phrenic nerve interruption
- (b) Intrapleural pneumonolysis
- (c) Extrapleural pneumonolysis
- (d) Thoracoplasty
- (e) Intercostal neurectomy
- (f) Scalenotomy

(3) Operations on the diaphragm
(4) Operations on the heart
(5) Removal of tumours of the chest wall

I. OPERATIONS ON THE RESPIRATORY TRACT AND PLEURA

Drainage of Acute Empyema

Before draining an empyema the following points must be considered —

(1) **The general condition of the patient.**—The common type of pneumococcal empyema is metapneumonic, that is, it does not develop or is not recognized until after the acute stage of the pneumonia is over, by which time the absorption of much of the pulmonary exudate has increased the vital capacity. These patients are not acutely ill, and can be safely drained by rib resection. The acute streptococcal empyemas, on the other hand, are usually synpneumonic, a large pleural effusion may develop rapidly, and so reduce the vital capacity

that the patients become desperately ill with severe dyspnœa cyanosis and rapid pulse rate In these circumstances the effusion must be removed with the least possible disturbance to the patient either by repeated aspiration or preferably by the insertion of an intercostal tube

(2) **The nature of the pleural exudate** —Diagnostic puncture should always be carried out before operation An empyema is localized by the pleural adhesions round its margins and when the pus is of creamy consistency these adhesions are sufficiently strong to prevent collapse of the whole lung when the empyema is drained On the other hand the thin watery fluid that is found in synpneumonic empyemas is a warning against exposing the pleural cavity to atmospheric pressure *The bacteriology is also important especially when the ætiology is in doubt* Likewise the odour and colour of the pus may suggest the cause of the infection

(3) **The extent of the empyema** —(*a*) With very large effusions causing marked displacement of the mediastinum even although of the *metapneumonic type sudden decompression allowing escape of* all the purulent exudate may be dangerous because of the sudden shift in the position of the mediastinum In such cases before under taking drainage by rib resection the mediastinum should be brought back to its normal position either by aspiration or by the insertion of an intercostal tube which is clamped so as to control the escape of pus

(*b*) In bilateral metapneumonic empyemas both sides should not be operated upon on the same day One side should be drained and the opposite side treated by aspiration followed by a drainage operation in a few days time

(4) **The age of the patient** —In infants the mediastinum is con siderably more mobile than in adults and open thoracotomy is therefore more dangerous Unless the pus from the empyema is very thick and the pneumonic process has completely cleared up it is unwise to resect a portion of rib in an infant

Drainage Without Rib Resection

For the drainage of an acute empyema in a patient unfit for rib resection the choice rests between intermittent emptying of the cavity by aspiration through a needle and continuous drainage by a rubber tube inserted through a cannula

The advantages of aspiration are that it can be done with slightly less disturbance of the patient and that it does not require any special *technique or post* operative nursing The disadvantages are that repeated puncturing every few days is unpleasant to the patient and frequently causes an infection in the chest wall The great advantage of continuous drainage through an intercostal tube is that the pleural cavity is kept empty and the lung is enabled to expand so that there is no unnecessary diminution in its respiratory function also occasion

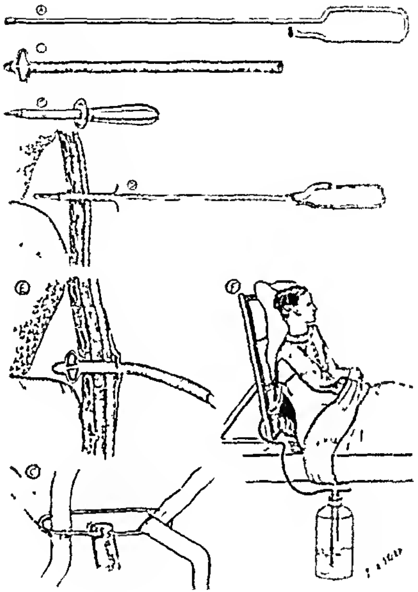
ally especially in children intercostal drainage will be sufficient no subsequent rib resection being required

The disadvantages are that the patient may pull the tube out the tube may become blocked with fibrin a tube of satisfactory size sometimes causes necrosis of the adjacent ribs and pain from pressure on the intercostal nerve and finally the patient requires two operations instead of one as drainage by rib resection is usually necessary at a later date Practically these disadvantages are minimal blocking of the tube with fibrin can be overcome by irrigation with a little normal saline rib necrosis and intercostal pain from pressure do not usually arise before it is time to resect a rib and the insertion of an intercostal tube is so simple that it is rarely considered an operation by the patient Therefore if adequate nursing is obtainable drainage through an intercostal tube is much to be preferred to repeated aspiration

(1) Repeated aspiration —The risk of infecting the chest wall may be diminished if when a suitable place for aspiration has been selected an incision about one inch long is made under local anæsthesia down to the intercostal muscle This wound is left open and dressed with vaseline gauze Subsequently aspirations may be made through this area without local anæsthesia and the danger of infecting the chest wall is avoided Later this incision may be enlarged for the rib resection (Tudor Edwards)

(2) *Drainage by intercostal tube* —*It is frequently preferable to do this with the patient in bed and with the least disturbance possible as it is an operation upon a very ill patient*

A trocar and cannula such as are employed for suprapubic drainage of the bladder or for thoracoscopy are required A Malecot s catheter stretched on a metal introducer that will pass through the cannula is chosen and its unstretched length measured so that it is possible to ascertain the length which projects inside the chest after insertion After infiltrating the chest wall with local anæsthetic down to the pleura an incision half an inch long is made down to the intercostal muscle of the selected space The trocar and cannula are introduced with caution so as to avoid trauma to the lung or diaphragm they should be kept close to the rib below so as to avoid injury to the intercostal vessels The trocar is withdrawn and the catheter immediately passed into the pleural cavity through the cannula and the latter removed from the chest wall the introducer is now withdrawn the catheter is immediately clamped to prevent the escape of pus or the entrance of air it is withdrawn until the surgeon estimates that about one inch projects inside the pleural cavity it is then fixed to the chest wall with a large safety pin and adhesive strapping The distal end of the catheter is joined by a glass connection to a rubber tube which is attached to a glass tube passing under water contained in a bottle under the patient s bed (Fig 173)



drainage is therefore not so satisfactory. Also, an empyema cavity is frequently lined by large masses of fibrin which, if a rib is resected, can be removed, and prevented from organizing and forming a thick layer of fibrous tissue over the lung; this allows more rapid re-expansion of the lung and obliteration of the empyema cavity.

Anæsthesia may be either local or general; if local is used, not only should the skin and muscles be infiltrated but also the periosteum on the surface of the rib and between the intercostal muscles above and below the portion to be resected. For general anæsthesia, nitrous oxide and oxygen, or cyclopropane and oxygen, are preferable to ether or chloroform.

The correct place for the drainage opening is on a level with the bottom of the cavity, so that when the patient is sitting or standing upright no pus can collect. This site is found by aspiration at several different points. It must be remembered, however, that a large basal empyema depresses the diaphragm; after drainage this rises and the costo-phrenic sinus tends to be obliterated, so that the ninth rib laterally, or the tenth rib posteriorly, are usually the lowest limits for resection.

The position of the patient for operation is that position which is most convenient for the surgeon; for example, if resection of a portion of the ninth rib in the posterior axillary line is indicated, the patient lies on the good side with the upper scapula rotated forwards. If the patient is not fit to lie in the required position, he is not fit for drainage by rib resection; temporary drainage by intercostal catheter should be used until there is sufficient improvement to justify rib resection. If there is a large bronchopleural fistula, the empyema cavity should be emptied of all pus by aspiration before placing the patient in a position which might make a large quantity of pus run through the fistula into the lung.

The incision is over the rib and parallel with it, and in an adult should be from three to four inches long. On exposing the rib, the periosteum must be incised for two and a half or three inches; at either end of the incision a cut should be made at right angles, so as to avoid leaving a small piece of rib uncovered with periosteum, which increases the chance of necrosis of the rib ends. The periosteum and intercostal muscles are stripped from the rib with a Farabeuf's rugine. Owing to the direction of the intercostal muscles it is important to work forwards on the upper margin of the rib when stripping them off, and backwards along the lower margin. (Fig. 174.) Finally, with a Doyen's raspatory the remaining portion of the periosteum is detached from the deep surface. After the portion of rib is excised, the aspiration is repeated to make certain that one is at the right level before incising the periosteum. When this has been ascertained, the empyema is opened by incising the posterior periosteum. It is advisable either to remove the periosteum or paint it with 10 per cent. formalin in order to prevent bone regeneration in the form of a ring

which may subsequently have to be removed before healing takes place The cavity should be explored with the finger so as to determine

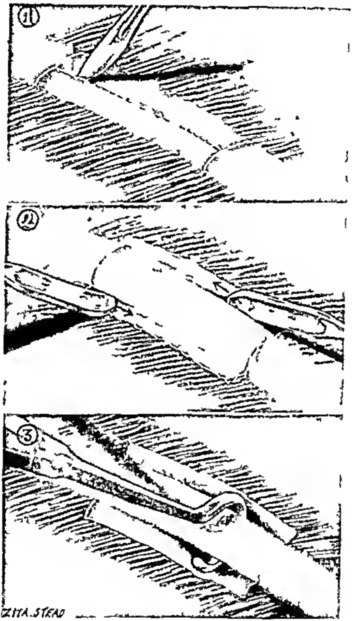


Fig 174 —Diagram showing the method of stripping the periosteum before resecting a portion of rib

whether the opening is low enough to secure dependent drainage and to open up loculi

In the postpneumonic empyema the cavity is usually filled with large masses of fibrin, which should be removed at the time of operation

with a pair of sponge forceps and by gently rubbing the walls of the cavity with gauze. The removal of fibrin should never be so rough as to break down any of the adhesions round the margins of the cavity.

For drainage, a large rubber tube should be selected, with an external diameter of about $\frac{3}{4}$ in. and the end cut obliquely. It is introduced just inside the pleura so that it rests on the floor of the cavity with the oblique opening facing upwards. A second tube of small external diameter (about $\frac{1}{4}$ in.) is passed alongside the larger tube to the uppermost limit of the cavity; this tube is later used for irrigation and is temporarily occluded with a spigot. The wound is closed tightly round the tubes in two layers by interrupted sutures. The tubes are fixed to the chest-wall with a large safety-pin and adhesive

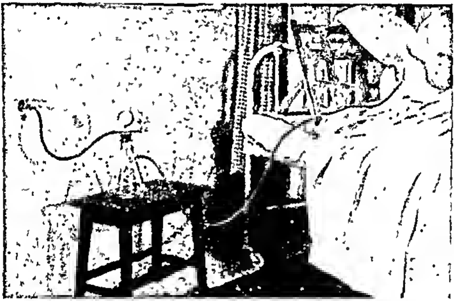


Fig. 175.—Negative pressure drainage by author's bottle with gauge and valve.

strapping. On return to the ward, the drainage-tube is connected with a bottle under the bed by a glass connector and rubber tube of the same size as the drainage tube. This bottle has a wide neck, and is half-full of water, with a short exit tube for air and a long glass tube that goes down one inch under the water; to this latter the rubber drainage-tube is connected. (Fig. 175.)

If anærobic organisms are the causative bacteria, as when a putrid lung abscess perforates into the pleural space, the empyema cavity should be packed with dry gauze and no attempt made to suture the incision; by this method there is less likelihood of post-operative spreading infection of the chest wall; the gauze is left *in situ* for the first three days after operation and is subsequently changed daily. If the fetor does not disappear in a week, the cavity should be packed with gauze soaked in 40 per cent. zinc peroxide paste. As soon as

the incision is covered with granulation tissue and the fetor has disappeared, the packing may be replaced by rubber tube drainage

Postoperative management. *Local*—Although it is unnecessary to maintain a negative pressure in the pleural cavity with a metapneumonic empyema it will, nevertheless, assist the closure of the cavity, and also help to keep the dressings clean, if the drainage tube is kept connected with the bottle under the bed for the first week or two

It is unnecessary to remove the tube more than once every seven days, when the skin is cleaned with ether and a fresh tube and pin replaced and fixed The adhesive strapping becomes soiled with the discharge, but so long as it retains its hold there is no need to replace it If the skin is painted with tinct benzoini co before each application of strapping, it does not become sore When the cavity is clean and the capacity is under 100 c c, the size of the tube is reduced but a small one must be left in until the lung is completely expanded

If facilities are available the size of an empyema cavity can be determined more accurately by measuring its capacity after filling it with a fluid opaque to X-rays (such as iodized oil or, if no fistula is present, barium emulsion) and taking radiograms in two planes Such X-ray films are most valuable in deciding when to remove the drainage tube

Irrigations are best performed with Dakin's solution or Eusol These contain free chlorine and should be freshly prepared at least once a week and kept in dark bottles away from the light, they can be used at full strength If they are not obtainable, normal saline solution is the next best, but on no account should hydrogen peroxide be used Instead of using the fluid for "mechanical" lavage, it is preferable to get the patient to lie down with the opening uppermost and to run the fluid in through the small catheter, thus allowing free exit for the displaced air When the cavity is filled the irrigating fluid escapes from the drainage tube irrigation of the whole of the cavity, including any recesses, is thus obtained The irrigations are started 48 hours after operation and on the first occasion saline is used in case there happens to be an unsuspected bronchial fistula The irrigations are repeated daily to begin with but are reduced in frequency when the cavity is clean These irrigations cannot be done so long as there are signs of a broncho pleural fistula, and the patient must be instructed that, if he suddenly starts to cough when the fluid is inside he must quickly sit up, or roll over, to get rid of it

The dressings should be changed once a day to begin with, and at the same time vaseline or ung calamine should be applied to the skin to protect it from the Dakin's fluid or Eusol

Breathing exercises greatly aid expansion of the lung, they are of two types —

(1) Blowing up an air ring, or blowing the classical coloured fluid from one bottle to another In this enforced expiration the air is forced from the sound lung over the bifurcation of the trachea and

the lung on the diseased side is expanded This method is of considerable antiquity but of doubtful value

(2) *Active inspiratory exercises* These are of much greater value The patient is taught to control both diaphragmatic and costal movement on the affected side, so that ultimately perfect function is restored If properly applied, these exercises reduce the incidence of chronic empyemas to a minimum Active exercises of the shoulder girdle and vertebral column are also of value in preventing scoliosis and thoracic deformity With the same object the patient should be encouraged to move about in bed after the operation and should get up as soon as the general condition allows

In this discussion on drainage of acute empyemas the terms " open " and " closed " drainage have been avoided owing to the varied definition given to them " Closed drainage may be used when the empyema cavity is at no time exposed to atmospheric pressure, this includes repeated aspiration and continuous drainage by intercostal tube which is connected to a water bottle

Chronic Empyema

There are three types of chronic empyema (1) Latent, in which the empyema, with or without a bronchial fistula, is not discovered until many months or even years after the acute onset (2) Persistent, in which the empyema persists for an abnormal length of time after the original drainage It may be draining more or less completely through the opening in the chest-wall or the opening having been allowed to heal, the pus may have re accumulated in the cavity The treatment of both the latent and persistent varieties is similar and they will be considered together (3) Tuberculous empyemas

Causation and Prevention of Persistent Empyema Cavity

A persistent empyema cavity may be caused by—

(1) The removal of the drainage tube before the cavity is completely obliterated This is by far the commonest

(2) The persistence of the infection in the empyema cavity, which may be due to any of the following causes—

(*a*) Failure to remove the fibrin from the cavity at the time of drainage,

(*b*) Failure to provide a sufficiently dependent drainage opening, so that there is a puddle of pus at the bottom of the cavity,

(*c*) Too long a drainage tube so that the pus can escape only by overflow, or too short a one, so that there is, between the end of the tube and the cavity, a sinus through which drainage will not readily occur

(3) Delayed expansion of the lung caused by—

(*a*) thick fibrous deposit on the visceral pleura due to persistence of the infection in the cavity,

(*b*) broncho pleural fistula,

(*c*) fibrosis of the lung

These last two are comparatively rare

(4) *A foreign body left in the cavity*, such as a piece of drainage material or, rarely, a portion of necrosed rib This is, unfortunately, too often found to be the cause

(5) Abnormal ætiology which was unsuspected at the time of drainage, such as tuberculosis, actinomycosis or growth

If an ordinary empyema is still discharging pus after four weeks, and is not healed at the end of eight, investigation should be carried out to discover the reason When there is an obvious cause, such as badly planned drainage or foreign body, this must be dealt with

Preliminary treatment of chronic empyema.—These patients are often suffering from long continued toxæmia They are anæmic, they have often lost a considerable amount of body weight, the cardiac muscles are degenerate, and some amyloid disease may be present They are, therefore, as a class, poor subjects for any severe operative procedures In most cases treatment should be begun by redrainage of the cavity at the most dependent point, taking the opportunity to obtain a piece of parietal pleura for histological examination If irrigation and breathing exercises are now carried out, the lung will, in many cases expand and further operation be rendered unnecessary If facilities are available, obliteration of the empyema cavity may be encouraged by applying a high negative pressure, by means of an electric or water pump to the tight-fitting drainage tube The negative pressure should always be measured and a leak valve should be inserted so that the pressure cannot exceed that decided upon Minus five centimetres of water may be used at first, rising to minus fifteen if bleeding or pain do not occur If expansion does not take place, further operation is postponed until the condition of the patient warrants it An empyema is not healed until the visceral and parietal layers of the pleura have come into contact *and united* If this cannot be accomplished by expansion of the lung, then the parietal pleura with the chest wall must be brought down in contact with the lung

Operations for Chronic Empyema

Discission (Ransahoff's operation).—This consists in making gridiron incisions through the visceral pleura down to the lung tissue in order to aid expansion of the lung and provide a new granulating surface over the lung for union with the parietal pleura In practice, the incisions do not result in any further expansion of the lung and new granulations on the visceral pleura are of no value in obtaining union of visceral and parietal pleuræ, as this readily occurs in their absence if the two are brought into contact The operation has therefore nothing to recommend it and should never be performed

Decortication.—As the lung is, so to speak, imprisoned by its fibrous coat, it may expand and fill the chest cavity if this layer of fibrous tissue is removed The removal, or decortication, seems an

ideal procedure but is not practical when the empyema is large owing to the difficulty of exposing the whole cavity It is not possible to anticipate in which cases it will be possible to find a plane of cleavage time does not seem to be a factor as this operation may be performed at the time of draining a latent empyema only a few months old or as in one of the author s cases in a persistent cavity of over seven years duration The operation is carried out by enlarging the original drainage opening by resection of one or two ribs and forcibly retracting the parietal layer An incision is made with extreme care through the deposit on the visceral pleura until the bluish grey tissue of the lung is exposed It may be possible to find a plane of cleavage between the visceral pleura and its encasing layer of fibrous tissue which is then carefully dissected off the whole of the visceral surface particularly at the angle where the visceral and parietal layers are in contact Although this operation has produced many striking successes the results are not sufficiently uniform to justify its use even when it is technically *feasible*

Thoracoplasty —When it has been found impossible to bring out the lung to the chest wall by prolonged drainage (with suction if available) and irrigation of the cavity with Dakin s solution then the chest wall must be brought down to the lung to obliterate the cavity by some type of thoracoplasty This operation must never be contemplated until the cavity has been really adequately drained for at least three months because even cavities that have persisted for years may clear up when properly drained A second and equally important reason for delaying thoracoplasty is that these patients are frequently suffering from chronic toxæmia with the associated myocardial changes amyloid disease or a severe anæmia may be present The condition of the patient will be much improved by adequate drainage and general treatment

The ordinary operation of thoracoplasty is not sufficient in chronic empyema because the thick rigid deposit on the parietal pleura will still keep the cavity open after the ribs have been resected The operation now to be described has been found highly successful in a large series of cases

Author s technique —The operation must be performed in two or sometimes three stages as it is rarely possible to do the whole operation in one sitting without severe risk to the patient s life In one two or three stages according to the size of the cavity the ribs overlying it must be resected subperiosteally The stages of decostalization proceed from above downwards and the drainage hole in the chest wall is sealed off at the time of operation so that with precaution the wound does not become infected from the sinus (For details *see* Thoracoplasty p 360)

The ribs must be resected well beyond the margins of the cavity when it lies posteriorly the reaction must be continued back to the transverse process and when the cavity extends nearly to the apex

the first rib must be taken (Fig 176) As the intervals between the stages of decostalization may have to be two weeks or more the regeneration of the ribs should be prevented by rubbing the periosteum with 10 per cent formalin At the final stage the wound is re opened and a flap is made of the outer wall of the cavity (Fig 177) In order to maintain the blood supply of this flap the cavity is incised along its anterior margin This includes division of the intercostal vessels which are ligated The incision is continued round the apex

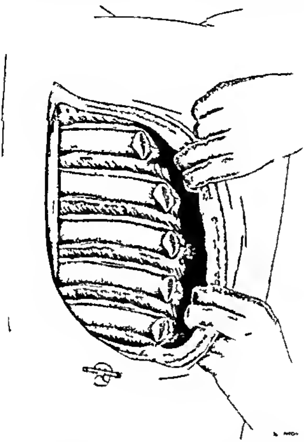


Fig 176 —Diagram showing decostalization over a chronic empyema cavity

of the cavity in such a way that the thickened parietal layer with the overlying intercostal muscles and periosteum form a pedunculated flap that is hinged posteriorly The section of the intercostal nerves does not cause weakness of the abdominal wall as the only nerves supplying the abdominal muscles which are divided are the seventh and eighth thoracic it is necessary to divide at least three nerves of supply to the abdominal musculature to produce demonstrable weakness

The whole of the inner lining of the cavity is now curetted thoroughly Where the visceral layer of thickened pleura runs into the parietal layer posteriorly a wedge of fibrous tissue is resected to allow the

chest-wall flap to hinge forward so that it will lie with the whole of the parietal surface in contact with the visceral, for if these two surfaces can be maintained in contact they will adhere, and obliterate the cavity. Gauze soaked in 1-in-1000 flavine to which an equal quantity of liquid paraffin has been added, is now placed on the outer surface of the chest-wall flap so as to hold it down. The musculo-cutaneous flap is next drawn forward on the outer surface of the pad of gauze and maintained

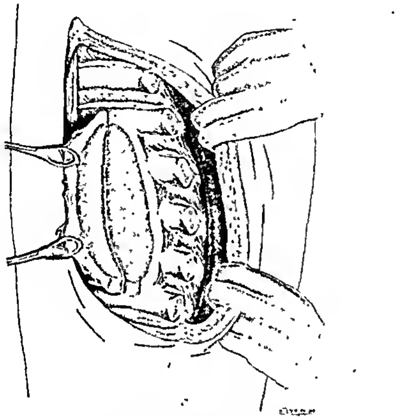


Fig. 177.—Diagram of posterior hinged flap made from the outer wall of the empyema cavity.

in place with a few sutures. (Fig. 178.) Another pad of gauze is then placed on the outer surface of the skin, and the chest-wall strapped tightly with adhesive plaster. Six days later the wound is re-opened and the flavine and paraffin pack that lies under the skin is removed; the musculo-cutaneous flap is sutured back into position, and a small drain left in for a few days.

This operation yields a higher percentage of cures than any other operative procedure (the percentage approximates to 100), and the final deformity is less marked than after the " de-roofing " operation initially described by Schede. Schede's operation is widely practised for the treatment of chronic empyemas: it consists of decostalization

over the empyema cavity, as in the author's operation, but the chest-wall flap consisting of the thickened parietal pleura, intercostal muscles and bundles and periosteum is excised completely instead of being utilized to help fill the empyema cavity. The musculo-cutaneous flap is thus *brought into direct contact with* the visceral *pleura to which it* adheres in successful cases. Any part of the cavity which cannot be obliterated with the musculo-cutaneous flap is packed with dry gauze and allowed to heal from the bottom by granulation tissue. The

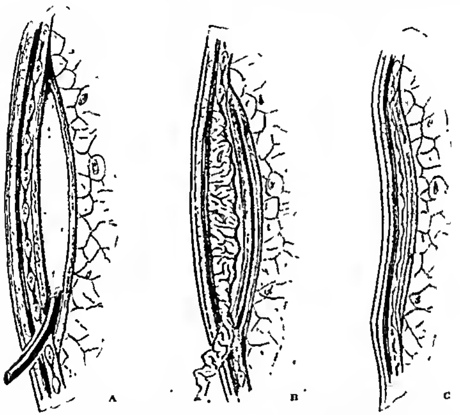


Fig. 178.—(A) *Longitudinal section through chronic empyema cavity before thoracoplasty.* (B) The operation completed; the gauze pack is seen lying deep to the skin *and extracostal muscles.* (C) *The end result, viz., complete adhesion between the* visceral and parietal layers of pleura.

procedure gives good results provided the chronic empyema cavity does not include the paravertebral gutter. Unfortunately this region frequently is involved

Operation by muscle graft.—Small residual empyema cavities, especially those with multiple bronchial fistulæ, may be filled with a pedicled muscle graft. (*See* p. 327.)

Tuberculous Empyemas

A pure tuberculous empyema (not secondarily infected) may develop spontaneously or, more frequently, it develops during the course of

treatment by artificial pneumothorax If toxic symptoms are not marked, the pus should be aspirated and replaced with air if it is considered essential to maintain the collapse of the underlying lung, the pleural pressures are maintained as in an uncomplicated pneumo thorax, in the other cases moderate negative pressures (8 to 12 cm of water) should be left at the end of each aspiration in order to encourage re expansion of the lung If toxic symptoms are marked the same regime should be instituted, but the pleural cavity should be irrigated at each aspiration If toxicity persists, continuous drainage by an intercostal tube is necessary

The great majority of tuberculous empyemas which are secondarily infected with pyogenic organisms require drainage by an intercostal tube but toxic absorption may often be reduced to a minimum and occasionally the secondary injection eradicated by pleural irrigations, and such treatment is worthy of trial in view of the great difficulty in completely obliterating a large tuberculous empyema after tube drainage

In any case in which there is a bronchopleural fistula sufficiently large to allow expectoration of the pus, continuous tube drainage is essential to prevent spread of the pulmonary disease from aspiration The drainage opening should be in the anterior axillary line, so as not to interfere with a subsequent thoracoplasty

Ultimately, when all toxic absorption has ceased the majority will require collapse by thoracoplasty, as it is rarely possible to get the lung to expand sufficiently to obliterate the space The operation should consist of simple decostalization over the cavity, followed, in drained cases, by the application of a high negative pressure to the drainage tube when this is available If there is a residual cavity after such treatment, the author's operation described for chronic pyogenic empyemas should be adopted it is not adopted in the first place owing to the likelihood of complication by tuberculous infection in the tissues of the chest wall

Technique of pleural wash-outs.—The patient is propped up in bed in a half-sitting position Two large-bore needles are introduced into the chest, one at the apex—usually the second interspace in front—and the other in the anterior axillary line at the bottom of the cavity, but not in the costo phrenic sinus A two way stop-cock is connected with the lower needle and the empyema is evacuated with a Potain's aspirator The stop cock is then turned and 0 2 per cent methylene blue run into the cavity The upper needle is connected with an artificial pneumothorax apparatus and, during the removal of the fluid, some air may be let in if the negative pressure becomes too severe When the fluid is being run in cessation of movement in the manometer indicates that the cavity is filled with fluid The fluid is then withdrawn, and the process repeated until the return is clear The cavity is left empty and with a negative pressure This procedure should be carried out weekly, or more often if toxicity is marked

There are a few cases in which aspiration, possibly combined with

pleural irrigations produces cessation of the re accumulation of pus and of toxic absorption but the lung is unable to expand to obliterate the space a thoracoplasty may be avoided in these patients by filling the cavity with oil thus converting the pyopneumothorax into an oleothorax

Drainage of Lung Abscess

Principles of the operation —(1) The exact localization of the abscess before operation both by physical signs and X rays is of the utmost importance so that it may be opened at a point nearest to the surface of the lung It must be remembered that a lung abscess may give no physical signs on examination by the ordinary clinical methods and localization will then depend largely on the radiogram a lateral view as well as a postero anterior being essential in some cases oblique views will aid in the accuracy of localization If doubt still exists as to the exact position of the abscess X ray examination after introduction of iodized oil into the bronchial tree may determine its position by showing an area into which the iodized oil does not enter In a few cases bronchoscopy may be required to determine from which bronchus the pus is being expectorated On no account should aspiration be employed for localization before the operation as this is very likely to be followed by empyema

The importance of accurate localization cannot be over-emphasized

(2) There must be firm adhesion between the two pleural surfaces in the field of operation before the lung is opened If the abscess is situated in apposition to the chest wall some adhesions may already exist but unless of long duration they are unlikely to be very firm It is impossible to discover the extent of these adhesions at the operation without running the risk of inducing a pneumothorax On this account the operation should almost always be done in two stages the object of the first being the formation of pleural adhesions over the area of lung to be subsequently incised All putrid lung abscesses are situated in the periphery of the lung and therefore in contact with the visceral pleura but the periphery of the lung includes the lung tissue adjacent to the interlobar fissures the mediastinal pleura and the diaphragm when an abscess occurs in one of these latter situations although pleural adhesions are present there are no adhesions between the lung and the chest wall through which drainage is to be performed Drainage must then invariably be done in two stages Another reason for two stages is the danger of an extensive infection of the chest wall if the pus from the abscess comes into contact with the tissues before a barrier of granulations has developed

(3) If the abscess has been present for several months with consequent loculation and surrounding secondary bronchiectasis a large drainage opening is required so that the loculations may be broken down and the cavity allowed to heal from the bottom by granulation tissue This necessitates removing a wide lid of tissue over the

abscess cavity This wide drainage is not required in those cases of acute putrid abscess which come to the surgeon before loculation and secondary bronchiectasis have occurred Such cases simply require drainage from the bottom and will heal rapidly without the resultant persistent bronchial fistulae which so often occur after wide de roofing The results of early drainage of acute putrid abscess have been excellent

In some patients with an abscess of many months duration lobectomy instead of drainage should be considered as the con

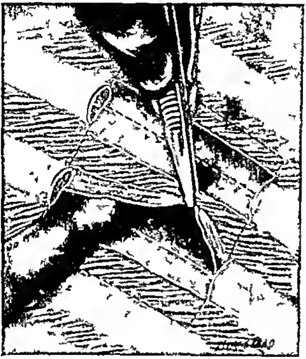


Fig 179 —Drainage of lung abscess A portion of two ribs has been excised The posterior periosteum has been incised and the intercostal muscles are being separated by a finger

valescence after drainage is very prolonged and the result is frequently unsatisfactory owing to the presence of secondary bronchiectasis On the other hand lobectomy can always be done after drainage when the general condition of the patient will have improved and the virulence of the broncho pulmonary suppuration diminished so that a fulminat ing post lobectomy empyema is less likely to occur

Technique *The first stage*—The position of the patient is that which gives easiest access to the area to be operated on it is preferable to have the table in slight Trendelenburg position so that any pus which escapes from the abscess into the bronchial tree may gravitate towards the larynx and be expectorated Local anaesthesia is preferable to any

form of general anæsthesia as the cough reflex is not then abolished and spread of the putrid pulmonary infection by inhalation is thus avoided If the patient is very nervous nitrous oxide and oxygen may be used

The site of the incision depends on the position of the abscess and it should be of sufficient extent to permit in the adult a resection of 3 inches of two ribs The lowest rib resected should be on a level with the lowest part of the abscess Having completed the rib resection the intercostal bundle must now be removed This is done by

Fig 180 —Drainage of lung abscess The ligated inter costal bundle is being removed and the intercostal vessels at the lower angle are being underrun

longitudinal incision through the posterior periosteum of the two rib beds and then with the utmost care not to puncture the pleura the intercostal bundle is dissected from the underlying parietal pleura with a blunt instrument or a finger (Fig 179)

The intercostal vessels and muscles at either end are ligated and the intercostal structures removed (Fig 180) To promote adhesions between the two layers a piece of gauze soaked in tincture of iodine is placed on the outer surface of the parietal pleura and the wound is temporarily closed with a small drain down to the gauze A piece of lead wire enclosed in a rubber tube is placed around the margin of the

prepared area of pleura (Fig. 181) before the second stage radiograms of the chest are made in two planes so that the relation of the cavity to the prepared area is clearly demonstrated

The second stage—The interval between the stages will depend on the state of the pleura as seen at the first operation and the urgency of the patient's condition If the parietal pleura is transparent and the lung can be seen moving under it an interval of seven days is desirable but where the pleura is thickened and adhesions are already present the interval need not be more than four or five days

Fig. 181—Drainage of lung abscess A lead wire enclosed in a rubber tube encircles the zone of cleared pleura and the gauze pack is being inserted

Local anæsthesia is preferable as in the first stage If nitrous oxide and oxygen are used (cyclopropane cannot be used as it is highly combustible) it is an advantage to have gas and oxygen anæsthesia under pressure when opening the lung because the pus is then blown out of the wound by the pressure of the gas instead of being sucked in

The incision is re opened and the gauze removed The lung is explored with a large-bore needle to find the exact position of the pus before incising the lung If the abscess is draining through the mouth it may contain only air which will be withdrawn into the syringe and has a peculiarly foul odour which distinguishes it from air that may have been aspirated from a bronchus For excising and removing the

tissue over the abscess the most satisfactory method is to use a diathermic current or the actual cautery at dull red heat so as to control hæmorrhage At the same time the assistant employs aspiration so as to keep the lung field dry If the abscess is of long standing it is desirable to remove the lung tissue overlying the outer surface of the cavity and also to open any auxiliary pockets into the main cavity If the abscess consists of a single cavity which has been present for only a few weeks a smaller opening at the lower limit of the cavity is sufficient The abscess cavity is packed with dry gauze and the margins of the wound covered with gauze smeared with vaseline No sutures should be applied to the skin or to the muscles of the chest wall as the main difficulty is to keep the superficial tissue from closing before the lung itself has healed

Postoperative treatment —The dressings are left undisturbed for the first two days after operation After this the dressing including the gauze packing in the abscess should be changed every 24 hours The wound is repacked with dry gauze and vaseline is used to prevent its adhering to the tissues of the chest wall If the discharge continues to be fœtid gauze packing soaked in 40 per cent zinc peroxide paste will rapidly remove the odour Later if the opening in the chest wall tends to contract so as to interfere with replacing the packing in the abscess cavity a large rubber drainage tube is passed down to but not into the abscess cavity and gauze packed tightly round it to maintain the opening in the chest wall

The patient should lie on the affected side as much as possible so that the pus may escape through the drainage opening instead of running the risk of being aspirated into the healthy side Expectoration of any material which escapes into the bronchial tree should be encouraged

The general treatment of the patient requires special attention Abundance of fresh air is necessary and blood transfusion will frequently be found advantageous Unlike cases of empyema there should be no hurry to get these patients out of bed cases of suppurative pneumonitis require prolonged rest The average case takes from two to six months to heal depending on the duration of the abscess before drainage and to a lesser extent on the size of the cavity

Postoperative dangers and complications —(1) *Hæmorrhage* is a serious complication Those nursing the patient should be forewraned and informed how to deal with the hæmorrhage rather than told to wait for the doctor A sterile package containing a six yard roll of gauze and two large artery forceps should always be kept beside the patient s bed As soon as the patient starts to cough blood the dressings are rapidly removed and the lung wound packed tightly with the dry gauze under the guidance of the eye If a definite area of the wound can be seen to be the origin of the hæmorrhage it is sometimes possible to pass a suture ligature round it The plugging may be removed with caution 48 hours later

(2) *Spread of infection in the lung*.—Small pockets of pus not discovered at the time of operation may keep up the infection in the lung. Occasionally the pneumonitis and abscess formation may spread slowly throughout the affected lung and even to the opposite side, with fatal results. Attempts should be made to drain any subsequent abscesses into the main abscess cavity.

(3) *Infection of the chest wall*.—Infection of the chest-wall is unusual when the operation has been performed in two stages. It is usually streptococcal and may be severe and widespread, requiring drainage by multiple incisions.

(4) *Broncho-cutaneous fistulæ*.—(*See* p. 327.)

(5) *Brain abscess*.—This is a disastrous but apparently uncontrollable complication.

Removal of Intrapulmonary Hydatid Cysts and Foreign Bodies

(1) **Hydatid cysts.**—A hydatid cyst in the lung will continue to enlarge until it eventually ruptures, usually into a bronchus and rarely into the pleural or peritoneal cavity. Occasionally, however, the cyst becomes secondarily infected and then simulates a lung abscess. The only satisfactory treatment is operative removal of the entire cyst. The operation is very similar in principle to that for lung abscess, in that accurate localization is essential, and adhesions must be present between the two pleural layers before opening the lung, to prevent sowing more cysts in the pleura. It is advisable not to perform the diagnostic puncture with a needle until the second stage of the operation, because this may cause rupture of the cyst into the bronchus.

Technique.—*The first stage* is exactly similar to the first stage for a lung abscess.

The second stage.—Having opened up the chest-wall flap and exposed the parietal pleura, the margins of the wound are protected with gauze soaked in 2 per cent. formalin to guard against the implantation of cysts in the incision. The lung is incised with a knife, or with a diathermy knife, until the wall of the cyst is exposed and identified by its dead white colour. It is preferable to remove the cyst intact, and this can be done if the contents are aspirated before removal; before pushing the aspirating needle into the cyst the patient (under a local anæsthetic) is made to hold his breath in inspiration, in case the cyst ruptures into a bronchus whilst being punctured. After aspirating as much fluid as possible, the syringe is disconnected from the needle, and with another syringe a few cubic centimetres of 5 per cent. formalin are injected into the cyst.

The cyst is composed of a white animal membrane and an adventitious membrane formed by the host which, in the lung, however, is an extremely thin layer of fibrous tissue. There is no connection between these two, therefore when the cyst is emptied it falls away from the walls of the adventitious capsule, and is usually coughed out through the opening in the lung. The whole animal membrane must be removed,

and the cavity in the lung should be carefully inspected for any pieces of white membrane

As the hydatid cyst is uninfected the wound may be closed without drainage The lung itself is not sutured but the muscles and skin of the chest wall are completely closed If the cyst is infected the remaining cavity is treated as a lung abscess

(2) Foreign bodies, including projectiles —Inhaled foreign bodies lie in the bronchial tree and must be removed through the bronchoscope otherwise they will give rise at some later date to a suppurative pneumonitis About 10 per cent of inhaled foreign bodies need removal through the chest wall Foreign bodies that have entered the lung through the chest wall lie in the parenchyma and are much less inclined to give trouble than those that have been inhaled If the foreign body is infected it may cause a lung abscess either shortly after the entrance or it may be many years afterwards Sometimes foreign bodies of irregular shape such as the projectiles from high explosives cause pain and frequent blood spitting and in these circumstances their removal will be required Metallic or other inert foreign bodies which have entered the lung through the chest wall should *not* be removed unless symptoms directly referable to them are present

Principles of the operation —(1) Accurate localization before operation is important This is carried out by postero anterior and lateral or preferably by stereoscopic X rays The operation is best performed on an X ray table and if possible with two X ray tubes working at right angles to each other so that the chest can be screened from the antero posterior and lateral fields without moving the patient An alternative but less satisfactory method is to screen on the day before operation The patient is first laid flat on his back and a mark made on the skin vertically above the foreign body He is then turned through a right angle and another mark made on the skin Finally he is put into the same position as he will be on the operating table and a third mark is made on the skin exactly over the opacity in the lung These allow the surgeon to visualize the plane on which he must look for the foreign body The general plan is to approach it by the most direct route from the parietes (2) Pleural adhesions Foreign bodies as a result of war injuries are often infected and it is desirable that the lung be opened without entering a free pleural cavity Usually in these cases pleural adhesions of some extent are found and moreover there is little chance of an empyema following the operation if the lung is kept out by positive pressure anæsthesia

Technique —Nitrous oxide and oxygen using a well fitting mask so that positive pressure may be applied if necessary are the preferable methods of anæsthesia The depth should be such that the patient will cough out any blood that enters the bronchi Resection of about three inches of one rib is usually sufficient but it may be necessary to resect portions of two The parietal pleura is exposed and if there are seen to be no adhesions the anæsthetist is warned to apply sufficient

pressure to keep the lung fully expanded An incision is now made down to the visceral pleura and the lung palpated from the surface By pressure on the lung with the finger, it may be possible to feel the foreign body in its substance If this is impossible, the visceral pleura is incised and the lung substance explored by gently pushing a finger into the lung When the foreign body has been felt, a pair of large artery forceps are pushed through the lung substance towards it By gently working with the forceps the foreign body can be freed from its adhesions to the surrounding tissue and then grasped and withdrawn The lung is repaired with a few deep catgut sutures, which may also be required to act as hæmostatic sutures if there is much bleeding The wound is closed with a small drain going down to the pleura but not into the lung

Treatment of Broncho-Cutaneous Fistula

Fistulæ following the drainage of a lung abscess usually close spontaneously when the infection in the lung has cleared, and in the greater number of cases no operation is required Closure is almost invariable after early drainage of an acute putrid abscess, persistent fistulæ result from delaying the drainage until much fibrous tissue surrounds the cavity To hasten closure the openings may be painted with solid silver nitrate, which destroys the epithelium and causes fibrosis

The number of fistulæ which will ultimately close under this régime is very large and many months should be allowed before deciding on operation, as a fistula does not incapacitate the patient Occasionally, however, the bronchial fistula is very large and will not close without operation There are two types of operation —

(1) When the broncho cutaneous fistulæ are open almost on the surface, the mouths of the bronchi are held open by the rigid scar tissue round the involved area In these circumstances closure is attempted by passing a probe into the fistula and incising the lung round it so that the track, with the probe in it, is isolated The base of the fistula is then crushed and ligated with catgut, and the lung tissue sutured over it

(2) More often the fistulæ open in a cavity which results from the drainage of a lung abscess No operation should be considered in these cases as long as the bronchial discharge is purulent, even after this has ceased, a long interval should be allowed for spontaneous closure The principle of the operation in these cases is to pack the cavity with a pedunculated muscle graft

Technique of muscle graft plombage.—An incision is made round the opening of the wound and all scar tissue is removed The incision is extended in a convenient direction to give good access to the available muscle, and a flap consisting of skin and subcutaneous tissue is raised This flap should be of generous proportions, as the amount of muscle required to fill the cavity is always more than at first sight appears necessary

A large flap of muscle is then outlined and freed The muscles

available in different situations are the pectorals, the latissimus dorsi, trapezius and serratus anterior. For high cavities the blade of the scapula may be resected up to the spine of the scapula and the muscles on its inner and outer surfaces made use of. In practice it is not necessary to retain the main vessels supplying blood to the muscle, as the muscle does not perish if a sufficient area of attachment to the chest wall is left.

Any epithelium which has grown over the wall of the cavity is destroyed by a diathermic button cautery, and the muscle flap pushed firmly into the cavity. It is essential that it should completely fill the cavity so that no chinks are left to fill with secretions. The flap is then firmly sutured in place with chromic catgut interrupted sutures. These should be passed through the surface of the flap at some distance from the edge, so that when all are tied the muscle is held firmly packed into the cavity. The skin wound is then sutured with a small superficial drain for a few days. Failure is due to taking too small a muscle flap and to suturing it too loosely.

Major Intercostal Thoracotomy

This operation is employed when it is desired to make a large opening into the thoracic cavity for diagnostic or therapeutic purposes. The technique will be described first, and then the various conditions for which the operation may be employed.

Anæsthesia.—The idea that it is dangerous to open the hemithorax without positive intrabronchial pressure in the absence of pleural adhesions or thickening of the mediastinum is incorrect. Two alternative forms of anæsthesia may be employed.

(1) Inhalation anæsthesia using cyclopropane or nitrous oxide combined with oxygen. The former has the advantage that at least 85 per cent. of the mixture is oxygen, whereas 15 to 20 per cent. is the maximum proportion of oxygen which can be used with nitrous oxide. Cyclopropane, however, is inflammable and therefore precludes the use of diathermy after the chest is open. In either case administration should be through an intratracheal tube which allows the intermittent aspiration of secretions which may gravitate into the trachea.

(2) Spinal anæsthesia. This has been advocated by some on the grounds that the cough reflex is maintained and permits the expectoration of infected secretion which may be expressed from the lung during the operation. Such cough as occurs is not very effective in expectoration and causes intrathoracic movement which is disturbing to both patient and surgeon.

Technique.—The patient lies on his good side with the upper arm pulled upwards and forwards. A pillow under the thorax helps to separate the uppermost ribs and increase the exposure when the chest is open. The table should be placed in slight Trendelenburg position so that secretions gravitate towards the mouth. As the operation is usually an extensive one, it is wise to insert a cannula in the internal

saphenous vein and begin saline infusion before starting Blood may then be substituted for the saline at any time during the operation this is of great value in maintaining the general condition during a prolonged procedure The approach is through an intercostal space, and for the upper lobe and superior mediastinum the 4th space is the best, and for a lower lobe the 7th (Fig 182) The incision runs from the costal cartilages in front, along the line of the desired interspace to within an inch of the spinous process of the vertebra, and

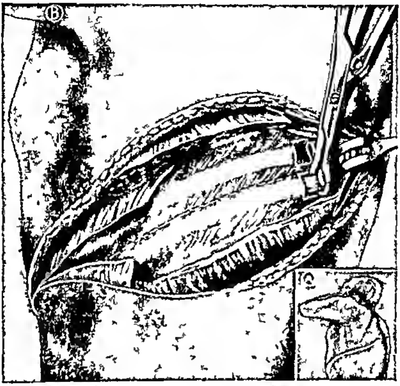


Fig 182 —Details of long intercostal incision for major thoracotomy

the superficial muscles are divided in the line of incision It is not until these have been divided that the scapula can be displaced sufficiently upwards and forwards to expose the 4th interspace The outer margin of the erector spinæ is incised and the muscle freed back to the transverse processes articulating with the ribs above and below the selected interspace With the muscle retracted backwards a one inch segment of each of these ribs is subperiosteally resected immediately lateral to the corresponding transverse process The intercostal tissues are then incised for the entire length of the incision down to the parietal pleura If a pneumothorax has been induced beforehand, this may rapidly be incised over the same distance In the absence of a pneumothorax care should be taken not to injure the underlying lung, particularly when adhesions between the two pleural layers are

present The intercostal vessels and nerve associated with the rib above and below the interspace incised are ligated and divided at their posterior ends in the position where a segment of each rib has been removed

Two hands are now inserted into the chest cavity, and steadily but firmly pulled apart until there is an opening from 4 to 5 inches wide A suitable rib retractor or spreader is inserted to maintain the opening, the margins of the intercostal wound being protected with gauze soaked in flavine solution so as to avoid wound infection

At the end of the operation, having removed the retractor, pericostal sutures are inserted, 1½ inches apart, *for the entire length of the intercostal incision* The most posterior of these sutures passes through the lateral margin of the erector spinæ, then round the two ribs and through the erector spinæ again, this is most helpful in closing the posterior end of the wound as it pulls the muscle over the divided ends of the

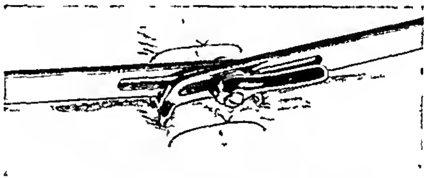


Fig 183—Rib approximator holding the ribs together, and two pericostal sutures (*British Journal of Surgery*)

ribs For holding the ribs together while the sutures are tied, hook retractors, or the author s rib approximator (Fig 183), are passed round the ribs above and below the incision, and drawn together by an assistant *The incision in the overlying muscles is repaired* with catgut and the skin with a continuous unabsorbable suture

Indications for major thoracotomy.—(1) Lobectomy or pneumonectomy, either for suppurative disease or neoplasm of the lung (An alternative approach for removal of the lung for neoplasm is discussed under " Pneumonectomy ")

(2) Mediastinal tumours, especially those lying posteriorly This includes neurogenic tumours which are almost always found in the posterior mediastinum or in the posterior part of the superior mediastinum to one side of the midline They project into the pleural cavity but are not adherent to the lung Through this approach they can easily be removed, but as they lie posteriorly it is usually sufficient if the intercostal incision is carried as far forward as the anterior axillary line

(3) Extensive war injuries of the chest, expecially those caused by high explosive The margins of the wound are excised down to the

pleura Foreign bodies from the lung and pleura are removed, badly damaged tissue is resected, and the lung repaired as far as possible with catgut sutures

(4) Operations for the repair of diaphragmatic hernia (except those occurring through the œsophageal hiatus into the posterior mediastinum which are better treated through an abdominal incision) The best approach is through the 8th interspace

(5) For transpleural approach to the œsophagus

Lobectomy

The operation here described is the one-stage procedure introduced by Shenstone and Janes of Toronto It has been shown to have a lower mortality rate than other methods It is obviously ideal for a chronic disease process confined to one lobe The majority of operations are performed for bronchiectasis The best results are naturally to be expected when the disease is strictly confined to one lobe however, bronchiectasis often includes the middle lobe when the right lower lobe is affected , likewise, on the left, the lingula process of the upper lobe may be diseased in addition to the lower lobe In such cases, the additional area involved should be removed as well as the lower lobe Bilateral cases are rarely suitable for surgery, but a few successful removals of both lower lobes have been reported Occasionally, when gross bronchiectasis in one lobe is combined with a small amount of disease on the opposite side, it is justifiable to remove the severely affected lobe as a palliative operation

Bronchial carcinoma, of the peripheral type with no X-ray or bronchoscopic evidence of mediastinal involvement, is an indication for lobectomy, but primary tumours of this type are unfortunately rare A chronic lung abscess or multiple abscesses confined to one lobe are best treated by this operation

Pre-operative preparation.—Pre operative examination of patients with bronchiectasis is most important It should include bronchoscopy, to exclude a foreign body or neoplasm as the underlying cause It is essential to obtain bronchograms of each lung with complete filling of all the bronchi so that the disease may be accurately localized The bronchi of *one* lung should be outlined with iodized oil and postero-anterior and lateral radiograms taken after one week or more the opposite lung is examined By using this method the bronchial trees of the two sides do not become superimposed in the lateral view

The amount of sputum should be reduced to a minimum before operating This is usually best done by continued postural drainage,* which may be enhanced by bronchoscopic aspiration in patients with a very large quantity of sputum

Phrenic paralysis—If diaphragmatic movements interfere with the division of adhesions the diaphragm may be temporarily paralysed by injecting the phrenic nerve with novocain close to its lower end The nerve should not be divided or crushed, as the diaphragm must

* Nelson H P, *Brit Med Journ* August 1934 ii [illegible]

be working if the remaining lobe is to return to its full and increased function

Artificial pneumothorax —The idea that a preliminary pneumothorax adjusts the patient for an open thoracotomy is a theoretical rather than a practical consideration Preliminary pneumothorax is unnecessary and should not be induced more than 48 hours before operation because if of longer duration expansion of the remaining lobe so as to fill the hemithorax may be delayed The chief value is that it aids expulsion of secretions from the diseased lung before operation

Technique —The anæsthesia and technique for opening the thorax have already been described under major intercostal thoracotomy (See p 328) For the lower lobectomy the 7th intercostal space is used

Division of pleural adhesions —The extent and type of pleural adhesions in cases of bronchiectasis vary greatly Rarely there are none at all Sometimes there are a few strands which are readily divided without producing hæmorrhage More commonly there are profuse adhesions which may be filmy avascular and readily separated or may be tough and vascular requiring division by sharp dissection and ligature to control the bleeding the latter type are most commonly met over the diaphragmatic surface of a lower lobe In the most difficult cases the two pleural layers over the diseased lobe may show almost complete symphysis in such cases it is sometimes easiest to separate the parietal pleura from the chest wall by blunt dissection All adhesions surrounding the diseased lobe must of course be separated This includes adhesions in the interlobar fissure which may be so unrecognizable that division of lung substance with the diathermic needle or between clamps is the only method of separating the lobes If adhesions are present over the remaining healthy part of the lung these should not be divided as they help to limit the extent of any postoperative empyema (which is inevitable when the lobectomy is done for suppurative disease) Surprisingly it has been found by experience that such adhesions do not hinder expansion of the remaining lung tissue necessary to fill the hemithorax Those uncommon cases in which the upper lobe is removed so that the lower lobe has to fill that side of the thoracic cage form a possible exception to this statement as adhesions over the remaining lung tissue are certain to prevent the expansion necessary to fill the apical part of the pleural cavity Even when divided sufficient expansion to fill this part of the chest may not occur and a later upper thoracoplasty is sometimes required

In lower lobectomy when all adhesions over the lobe have been separated the pulmonary ligament is divided between clamps up as far as the inferior pulmonary vein the tissue in the clamps on the mediastinal side should be ligated A pedicle will now be produced round which the operator s finger and thumb should be able to meet Care should be taken not to draw up the diaphragm and cut it when dividing basal adhesions When working in front of the vertebral

bodies the extreme proximity of the opposite pleura in this position must be remembered, and in this region the œsophagus on the left and inferior vena cava on the right must be noted and most carefully avoided

If any bleeding vessel on the pericardium is picked up with pressure forceps it should always be ligated, as the piece of tissue crushed by the forceps may slough and lead to a pleuro-pericardial fistula and death from pericarditis If an opening is made into the pericardium

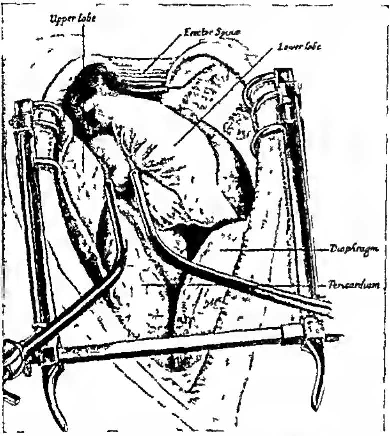


Fig 184 —Lobectomy Shows the long intercostal incision with the ribs spread and the two tourniquets in position before amputation of the left lower lobe (*British Journal of Surgery*)

during the process of separation of adhesions, it should be carefully closed with a very fine suture

Application of tourniquets and the removal of the lobe—The loop of a tourniquet* is slipped over the diseased lobe and kept as high up the pedicle as possible while the cord is wound in and tightened A second tourniquet may be tightened up round the lung $2\frac{1}{2}$ in distal to

* The Roberts Nelson tourniquet consists of an oval tube which is 8 in long and bent in the middle to an angle of 140° The end that comes against the pedicle is slightly splayed out and has thick lips while at the other end is a drum on which the cord of the tourniquet is wound The tube is threaded from the drum end, with a loop of thick blind-cord the loose ends of which are knotted together and are then attached to the drum by fitting into a groove on the rim The drum will wind in either direction, but when the ratchet-catch is applied the cord can only be wound up In practice the catch is not used until most of the loop has been wound in It is then applied and the cord steadily tightened up round the pedicle

the first in order to prevent escape of pus and blood from the diseased lobe, but the necessity for this may be avoided if material which escapes from the lobe during section of the pedicle is aspirated. The cord is held in place by the surgeon while the assistant tightens up the tourniquet (Fig 184). The pleural cavity is packed off with four or five large gauze packs soaked in flavine solution (1 in 1,000). The pedicle is then divided with curved scissors $\frac{3}{4}$ in distal to the tourniquet (the proximal tourniquet if two are employed), in children, more than

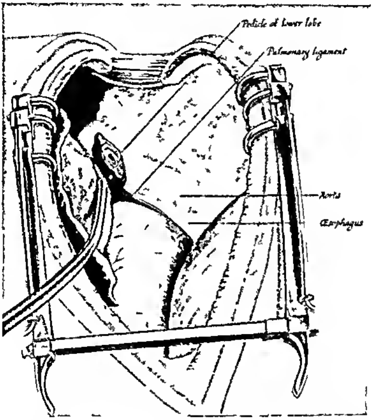


Fig 185—Lobectomy The pedicle immediately after removal of the lower lobe (*British Journal of Surgery*)

one inch should be left distal to the tourniquet as the tissues retract more than in the adult. While dividing this, the surgeon must constantly note his relation to the tourniquet, and the assistant will find that he can tighten up the cord two or three more points on the ratchet. As the section proceeds the assistant should apply long clamps to the proximal ends of the large vessels and bronchi so that they cannot retract through the tourniquet. Any pus that escapes must be removed by suction or carefully mopped up with small swabs on holders. When the lobe has been removed the pedicle is swabbed with 1 in-1,000 flavine solution and then the gauze packs are removed (Fig 185)

Closure of the pedicle —The cut end of the pedicle projects for about ½ in beyond the proximal tourniquet and presents a central white area consisting of blood vessels and bronchi and a small margin of grey lung tissue The pedicle is sutured with No 4 40 day chromicized catgut on a round-bodied half-circle needle This suture is continuous and passes through all the tissue in the pedicle, a second exactly similar suture is inserted, this being tied in addition to each end of the first suture These sutures occlude the bronchi and vessels and draw them together (Fig 186) The tourniquet is now relaxed a little and, if there is no hæmorrhage, is completely removed There may,

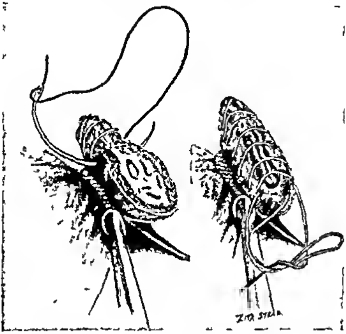


Fig 186 —Lobectomy The two layers of continuous sutures through the pedicle

however, be one or two points on the pedicle which bleed and require to be picked up with forceps and sutured or ligated, but usually no bleeding of consequence occurs

Before removing the retractor, the pleural cavity must be carefully inspected for any oozing vessels, the most frequent sites being on the diaphragm and in the region of the pulmonary ligament Those on the diaphragm are best controlled by sutures and not by simple ligature The diathermic current is of great assistance in coagulating areas on the chest-wall which are difficult to tie

Drainage —The skin and extracostal muscles are retracted, the lateral surface of the ninth rib exposed in the scapular line and an inch of the rib excised by the ordinary subperiosteal resection A stab incision is made through the skin and extracostal muscles into the

chest and a drainage tube is drawn from within outwards. The intrathoracic portion of this tube has several side openings, is about 4 in. long, and projects towards the stump; it should not be sufficiently long to come into contact with the mediastinum. Some surgeons advocate an ordinary stab incision without resection of a piece of rib, but it has been found that if the tube is large enough for drainage it causes pain from pressure on the intercostal nerve and may become obstructed. The chest is now closed as described under major intercostal thoracotomy (p. 330).

Right Middle Lobectomy

When this is to be combined with removal of the right lower lobe one of two methods may be employed. If the oblique fissure is easily defined and the middle and lower lobes easily separable, the most satisfactory procedure is to remove the lower lobe first and then remove the middle lobe in an exactly similar manner. Where the oblique fissure is obliterated by dense adhesions, the lower and middle lobes may be included in a single tourniquet and removed together. This method is not quite so satisfactory, as the pedicle is rather large.

If the middle lobe only is to be removed, the technique already described is used, but care should be taken that the pedicle is long enough to avoid kinking or injury, with resulting œdema of the lower lobe bronchus. Such damage has been found to cause difficulty in expectoration of secretions from the lower lobe and sometimes atelectasis with subsequent bronchiectasis.

Removal of the lingula of the left upper lobe.—This is usually combined with removal of the lower lobe; the lobectomy should be completed first. The lingula is then freed from all adhesions and, except for its broncho-vascular trunk at the hilum, separated from the rest of the upper lobe by division between clamps or with the diathermic current. This leaves a small pedicle near the hilum which may be divided between large curved clamps, thus completing removal. A simple transfixion ligature using No. 1 40-day chromicized catgut is usually sufficient to occlude the bronchus and vessels in the stump. When separation from the rest of the upper lobe has been performed between clamps, the clamps on the upper lobe should be removed after suturing the divided lung substance. It is unnecessary and inadvisable to attempt to bury these sutures by a second row as is done in intestinal surgery.

Postoperative treatment.—The drainage tube should be connected by a piece of rubber tubing to a glass tube passing under water in a bottle, as in empyema drainage; this should be done before the patient leaves the operating theatre, so that the air in the pleural cavity may be expelled at the earliest possible time and the remaining lobe encouraged to fill the hemithorax by increased expansion. This under-water drainage is continued for about three weeks, the discharge being at first sero-hæmorrhagic fluid and later pus; at the end of this period the tube is cut flush with the chest wall and allowed to drain into the

dressings The size and length of the tube are subsequently controlled exactly as in any case of empyema drainage

Oxygen is useful in avoiding suboxygenation during the immediate postoperative period, it is not necessary but helps to keep the patient's general condition as good as possible The patient should be encouraged to expectorate all sputum in order to avoid any retention of sputum, it is advisable to change the position in bed every two hours If the sputum is very sticky, ammonium chloride, grs x in capsules given four hourly, will loosen it Steam inhalations from water containing tinct benzoin co (1 drachm to the pint) may be used to attain the same object

Postoperative complications.—(1) *Reactionary hæmorrhage*—Severe hæmorrhage occurs into the pleural cavity and escapes from the drainage tube after return to the ward Such cases are now very rare Treatment consists in immediate blood transfusion If the hæmorrhage continues, it is necessary to take the patient back into the theatre, open up the wound and find and secure the source of the bleeding

(2) *Secondary hæmorrhage*—This fortunately is also rare in spite of the fact that large vessels are ligated in the presence of infection If severe but not immediately fatal the patient should be transfused, if the hæmorrhage continues, the wound must be re-opened and the source either controlled by ligature or the localized empyema cavity surrounding the stump packed firmly with dry gauze

(3) *Empyema*—A localized basal empyema extending to the stump and drained by the tube is almost invariable when the lobectomy has been done for suppurative disease, and it is not considered a complication When the pleural space becomes loculated, owing to incomplete expansion of the remaining lobe (*vide infra*), fluid may collect which cannot escape from the drainage tube After lower lobectomy, such collections are usually found above and anterior to the incompletely expanded upper lobe The fluid should be aspirated through a needle, occasionally it is not infected, in which case any re-accumulation should be treated by further aspirations More frequently, infection is present and drainage by an intercostal tube is indicated

(4) *Broncho-cutaneous fistula*—Most patients develop a bronchopleural fistula which communicates to the exterior through the drainage tube during the second or third week, or sometimes later After the first week, it causes no disturbance to the patient and, as the bronchial opening communicates with the exterior by a long track, it almost invariably heals spontaneously as the drainage tube is gradually shortened It should not therefore be considered a complication but rather a frequent event during convalescence

(5) *Delayed or incomplete expansion of the remaining lobe or lobes*—This is one of the most common and unfortunate complications of lobectomy Instead of expansion of the upper lobe (and middle lobe on the right side when not removed) within a few hours of closure of the chest, so as to fill the hemithorax except for the area immediately around the stump and drainage tube, there may be either complete

collapse against the hilum or, much more commonly, sufficient re-expansion to reach the lateral chest-wall, but insufficient to fill the apical part of the pleural cavity. Occasionally full expansion occurs immediately after operation and partial or complete collapse develops during the first postoperative week.

Some of these cases are due to obstruction of the bronchus by mucus, and patients should therefore be encouraged to expectorate all sputum. If there is complete absence of aeration of the lobe 24 hours after operation, bronchoscopy should be carried out and the bronchial secretions aspirated. Loculations of the pleural cavity due to incomplete expansion of the upper lobe have already been discussed. The effect on the lobe itself varies. Sometimes slow but complete re-expansion of the lobe occurs, leaving no permanent damage. In other cases, the delayed expansion results in a bronchiectasis not present before operation. In the most serious cases suppurative pneumonitis or actual abscess formation complicate the collapse. In these the remaining lobe should be removed if the general condition of the patient will allow.

(6) *Infection of the opposite lung*.—A mild degree of bronchitis, lasting a few days, in the opposite lung is quite common. All grades and types of infection, including suppurative bronchitis, pneumonitis and bronchopneumonia, are seen occasionally. Lobar atelectasis may complicate such infective processes and should be recognized so that active measures may be taken to relieve the bronchial obstruction.

(7) *Wound infection*.—This is most uncommon. When it does occur, the infected part should be laid open and packed.

(8) *Suppurative pericarditis*.—This is rare but usually fatal. Injury to the pericardium at the time of operation does not necessarily result in infection if the wound is sutured. Pericarditis may occur when the pericardial sac has not been opened.

(9) *Brain abscess*.—Blood-borne infection to the brain is a rare but invariably fatal sequel.

(10) *Suppurative mediastinitis*.—This is also extremely rare after lobectomy, but has occasionally caused death after pneumonectomy.

(11) *Late development of pleuro-pulmonary tuberculosis*.—This has been noted by most surgeons who have completed a large number of lobectomies. It is possible that the application of the tourniquet and suture of the pedicle crushes glands containing tubercle bacilli which are then set free in the blood stream.

PNEUMONECTOMY

For suppurative disease.—Unilateral bronchiectasis which involves all the lobes on the affected side can only be cured by removal of the whole lung. Before such an extensive operation, it is essential to make sure that there is no disease in the opposite lung, by bronchograms which outline the entire bronchial tree on the healthy side. The likelihood of the patient withstanding the operation and its immediate sequelæ must be carefully considered; in general, children

are much better operative risks than adults The risk in adults depends more on the duration of the symptoms than on the severity of the disease at the time the myocardium of patients who have had suppurative bronchiectasis for many years is enfeebled by toxic changes

Very occasionally a large lung abscess which has spread across the interlobar fissure and affected both upper and lower lobes may be an indication for pneumonectomy Rarely, unilateral congenital cystic disease which has become infected may warrant total excision of the affected lung

If pneumonectomy is agreed upon the pre operative treatment and anæsthesia are exactly similar to those for lobectomy

The exposure is obtained through the 5th or 6th intercostal space in the manner described under major intercostal thoracotomy Adhesions between the visceral and parietal pleura are all separated and the pulmonary ligament is divided between clamps, so that the lung remains attached to the mediastinum by the hilar structures only Division of the pedicle is carried out exactly as in lobectomy, except that the tourniquet encircles the hilar structures of a whole lung instead of those passing to one lobe Care should be taken that the proximal tourniquet is not placed too close to the mediastinum, so that injury to the pericardium may be avoided Suture of the stump, drainage and closure of the chest are similar to those in lobectomy

Some surgeons advocate dividing the operation into two stages if there are gross pleural adhesions over all lobes i e , the lower lobe is removed at the first operation and the upper (together with the middle on the right side) at a second stage This is rarely necessary if the general condition of the patient is maintained during the operation by continuous transfusion and has the great disadvantage that extension of the suppurative process in the diseased lobe left behind after the first stage may result in death

The complications which may follow lobectomy may also occur after pneumonectomy, except of course, those associated with incomplete expansion of the upper lobe

As the whole lung has been removed a total empyema follows In children and in many adults, this space becomes obliterated spontaneously by shift of the mediastinum rise of the diaphragm and contraction of the chest-wall In some adults, these compensatory mechanisms diminish the size of the cavity but do not result in complete obliteration If this happens, it is necessary to perform a thoracoplasty several months after operation so that the chest wall is brought into contact with the mediastinum

For neoplasm.—Bronchial carcinoma more commonly affects the large than the small bronchi (in a proportion of about 3 1) Lobectomy for the peripherally situated growths has already been mentioned When the tumour is situated in a large bronchus but more than one inch from the bifurcation of the trachea, removal of the whole lung by separate ligation of each of the structures forming the pedicle offers the best chance of cure This method makes it possible

to divide the main bronchus much closer to the tracheal bifurcation than when a tourniquet is used Division of the pedicle in pneumonectomy for neoplasm is therefore totally different from that for suppurative disease for which the tourniquet technique is perfectly adequate

Pre-operative evidence that a growth is inoperable may be revealed by —

(1) Palpable metastases *in* the supra clavicular or axillary lymphatic glands

(2) Blood borne metastases in the bones (especially the long bones and skull) liver brain or elsewhere

(3) The radiographic demonstration of widening of the mediastinum or of a pleural effusion (the latter *is not* absolute evidence of inoperability) or of paralysis of the phrenic nerve

(4) The endoscopic demonstration of paralysis of the left recurrent laryngeal nerve or fixation of the trachea or main bronchi or widening of the carina or extension of the growth to less than one inch from the tracheal bifurcation

In those cases which appear to be operable the chest should be explored

In addition to bronchial carcinoma some cases of bronchial adenoma may be treated by total pneumonectomy the technique is similar to that for carcinoma in most cases as these non invasive tumours usually arise from one of the large bronchi

The best exposure is usually obtained by a postero lateral incision through the 5th intercostal space by the method described under major intercostal thoracotomy An alternative approach through the anterior chest wall with the patient lying on his back may be used when a pre-operative artificial pneumothorax has shown that there are no or few adhesions over the lower lobe it gives ready access for the separation of adhesions over the upper lobe and possibly causes less interference with respiration during the operation but air tight closure of the pleural cavity is almost impossible and costal cartilage necrosis may complicate convalescence

The anterior approach—With the patient lying on his back and the arm on the affected side abducted a curved incision convex downwards is made from the angle of Ludwig in the mid line to just behind the mid axillary line the lowest part of the curve is in the mid-clavicular line where it reaches the level of the 4th interspace The incision extends down to the ribs and intercostal structures by division of the pectoral muscles in addition to the skin and subcutaneous tissues The 3rd intercostal space is exposed by separating the pectoral fibres from their origin and raising a flap which is retracted upwards The pleural cavity is opened by an incision through that part of the 3rd interspace exposed i e from the lateral border of the sternum to the mid axillary line The internal mammary vessels must be doubly ligated *before* extending the incision as far as the sternum The 3rd and usually 4th costal cartilages are divided

with a knife close to the sternum A Tuffier rib retractor is inserted at each end of the intercostal incision and the ribs separated as much as possible with these If the exposure is inadequate the 2nd costal cartilage may be cut and if necessary the 3rd or 4th ribs divided at the lateral end of the *incision*

Closure of the anterior incision —Interrupted pericostal sutures are used to draw the ribs together The divided costal cartilages may be approximated by sutures passing through their substance if the cut surfaces are not sufficiently adjacent after insertion of the pericostal sutures but cartilage necrosis is probably thereby encouraged This closure is rarely air tight The musculo cutaneous flap is sewn down over it by interrupted catgut sutures in the pectoral muscles and a continuous unabsorbable suture in the skin A dressing should be firmly fixed in position with adhesive strapping in order to prevent air being forced into the interstitial tissues and paradoxical movement of the chest wall

Removal of the lung by individual ligation —Whatever approach is employed the *feasibility* of total ablation of the growth by surgery must be decided as soon as possible after opening the chest Adhesions may have to be divided before any decision can be made If the growth has invaded any irremovable structure or if there is extension into the mediastinal glands the chest should be closed at once without drainage any excess postoperative effusion is treated by aspiration

If no evidence of extension beyond the limits of surgical excision is found adhesions between the visceral and parietal pleura are separated and the pulmonary ligament is divided between clamps as described under pneumonectomy for suppurative disease An incision is then made in the mediastinal pleura close to the lung root By careful blunt dissection the two pulmonary veins and the homolateral branch of the pulmonary artery are isolated from the other structures in the pedicle The artery is *first doubly ligated* as *proximal* as possible with strong catgut A pair of large curved forceps are then placed on the distal end by pressing them into the lung a good length of the vessel is left beyond the ligatures when the vessel is divided close to the forceps The two veins are similarly treated This leaves the lung attached by the main bronchus with the bronchial arterial supply lying on its posterior surface The small arterial branches are separated from the bronchial wall clamped divided and ligated The mediastinal tissues are separated from the bronchial wall by blunt dissection almost to the tracheal bifurcation A clamp is now placed on the bronchus which is divided on the distal side of the clamp thus completing the separation of the lung Interrupted *silk* mattress sutures are inserted through the bronchus at the same level thus compressing *it from* before backwards like the fish tail on an exhaust pipe The clamp is removed and the divided end of the bronchus is most carefully sutured with a continuous silk suture Finally the opening in the mediastinal pleura is drawn over the divided pedicle so that the bronchial stump is buried

Closure of the chest has already been described. Unless there has been *gross* contamination of the pleural cavity no drainage is employed. Before returning the patient to the ward a needle connected to a pneumothorax apparatus should be inserted and air withdrawn until the pressures read about −6 −10 cm of water

Postoperative care and complications.—These cases differ from lobectomy and pneumonectomy for suppurative disease in that no drainage is employed so that the hemithorax fills with blood stained serum fibrin is formed and later organizes so that the ultimate outcome is a hemithorax containing a mesh work of fibrous tissue with fluid in the meshes and much reduced in size by shift of the mediastinum rise of the diaphragm and contraction of the chest wall. Obviously this requires primary and permanent healing of the divided bronchus. If a broncho-pleural fistula develops the patient is likely to aspirate a large amount of pleural fluid into the opposite bronchial tree and if he survives infection of the pleural space is almost certain to follow. Those in immediate attendance should be warned of this catastrophe and instructed to turn the patient immediately on to the side operated on if it occurs. A trocar and cannula for insertion of an intercostal tube should be kept sterile at the patient's bedside so that drainage may be instituted at once

MEDIASTINOTOMY

Extrapleural exposure of the mediastinum is very rarely practised since it has been realized that a transpleural approach gives much better access to tumours of the mediastinum and to the œsophagus without increasing the operative risk. The indications are —

(1) For the drainage of a mediastinal abscess
(2) To permit the escape of air in a case of mediastinal emphysema.
(3) For removal of a retro sternal goitre

(1) POSTERIOR MEDIASTINOTOMY

Suppuration occurs most frequently in the posterior mediastinum and if a localized abscess forms extrapleural drainage is indicated

Before operation the exact position of the abscess relative to the posterior ends of the ribs must be determined by antero posterior and lateral radiograms

Technique. *Anæsthesia*.—It is an advantage to have the patient breathing shallowly in order to decrease the chance of tearing the pleura. This is best obtained with cyclopropane and oxygen administered through an endotracheal tube

A slightly curved incision is made with the concavity directed laterally running down the lateral border of the sacrospinalis muscle. The overlying extracostal muscles are divided in the line of the incision. The removal of the posterior segments of three ribs is usually sufficient to provide adequate drainage. In an adult about 3 in of each rib together with the tips of the corresponding transverse processes are resected. To do this the sacrospinalis muscle is retracted medially

but not divided The periosteum in the medial part of one rib bed is incised so as to open the endothoracic space without opening the pleural cavity, by gentle blunt dissection the pleura is separated from the intercostal bundles and periosteum opposite the tips of the partially-resected transverse processes The intercostal bundles are ligated and divided With extreme care the parietal pleura is stripped from the medial ends of the ribs and vertebral bodies with the finger

This separation may be extended upwards and downwards deep to the intact ribs in order to increase the exposure If the pleura is torn, it should be carefully sutured and the wound packed the actual drainage of the abscess should then be delayed for four or five days until the opening has become sealed off When the abscess is reached, it should be opened up widely, the pus evacuated and the cavity packed with dry gauze, the edges of the wound being protected with vaseline gauze The cavity is allowed to heal from the bottom as in a lung abscess

(2) MEDIASTINOTOMY TO PERMIT THE ESCAPE OF AIR FROM THE MEDIASTINUM

In mediastinal emphysema a swelling may be found in the suprasternal notch, due to air which has extended upwards This condition is sometimes fatal from the pressure of the air on the veins in the mediastinum It may be successfully treated by a transverse incision at the suprasternal notch, the superior mediastinum is then entered with the finger in the same plane as the superior vena cava, when the air will escape from the wound and can be assisted by using a cupping glass connected to a suction pump

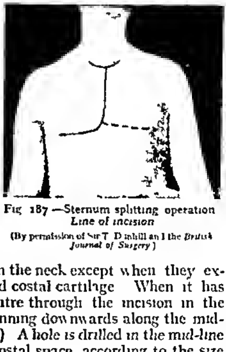


Fig 187 —Sternum splitting operation Line of incision

(By permission of Sir T Dunhill and the *British Journal of Surgery*)

(3) ANTERIOR MEDIASTINOTOMY BY A STERNUM-SPLITTING OPERATION

Retrosternal goitres, for which this operation may occasionally be required, can usually be delivered through the ordinary collar incision in the neck except when they extend down below the level of the 2nd costal cartilage When it has been found impossible to deliver a goitre through the incision in the neck, a vertical incision is added running downwards along the midline to expose the sternum (Fig 187) A hole is drilled in the mid-line on a level with the 2nd or 3rd intercostal space according to the size of the intrathoracic goitre with a Doyen's brace, and enlarged to about 16 mm with a burr

The sternum is now divided transversely by cutting through the bone on either side of the hole with bone forceps, and longitudinally

in the mid line first with a saw and then with sternum cutting forceps (Fig 188) The two sides are forcibly retracted for about 4 in It may be necessary to incise the intercostal space on each side at the level of the transverse bone division, in which case the internal mammary vessels should be sought for and ligated At the end of the operation, the split sternum can be maintained in approximation with catgut sutures through the external periosteum but, if a wide gap persists, each side should be drilled and wired together, or sutures of No 4 chromic catgut can be passed right round the sternum

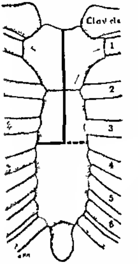


Fig 188 —Line of division of sternum.
(By permission of Sir T Dunhill and the *British Journal of Surgery*)

As soon as it is ascertained that a retrosternal goitre cannot be delivered through a collar incision in the neck, before proceeding to split the sternum, the anæsthetist should insert an endotracheal tube through which the anæsthetic is administered, if one is not already in place, as this allows the use of positive pressure in those cases in which both pleural cavities are accidentally opened, even if there is laryngeal spasm

Removal of Tumours of the Mediastinum

Apart from retrosternal goitres, tumours of the mediastinum are best removed by a transpleural route Those in the posterior mediastinum are best exposed through a postero-lateral incision as described under major intercostal thoracotomy Those in the anterior mediastinum or anterior part of the superior mediastinum are most commonly teratomas and usually project more into one pleural cavity than the other When they are very large and the contents fluid, the fluid may be aspirated to reduce the size of the tumour but every effort should be made to remove it in one stage

Exposure for a teratoma is obtained either by the anterior approach described for some cases of pneumonectomy or by the method described under major intercostal thoracotomy

The danger of opening both pleural cavities is present, as with intrathoracic goitres anæsthesia should therefore be given through an endotracheal tube The tumour is carefully separated from the surrounding mediastinal structures, chiefly by blunt dissection Usually the blood supply enters over a localized area; the blood-vessels at this point should be clamped, divided and ligated As the mediastinum is generally fairly mobile, any extension to the opposite side of the mid-line may be exposed by traction on the tumour

When an uninfected tumour of the mediastinum is removed, the subsequent sero hæmorrhagic pleural exudate may either be allowed to drain into a water-seal bottle through an intercostal tube inserted

at the time of operation, or be treated by aspiration If a tube is used, it may be taken out after a few days It is not necessary to drain by rib resection as in lobectomy

II. OPERATIONS FOR REDUCING THE SIZE OF THE THORACIC CAGE, *i.e.*, SURGICAL COLLAPSE THERAPY

Phrenic Nerve Interruption

The hemidiaphragm may be paralysed temporarily (for a period varying from four to nine months) by crushing the phrenic nerve and any accessory branches in the neck, or permanently by evulsing the nerve

A case should be very fully considered before proceeding to evulse the nerve, as atelectasis of the lower lobe is much more frequent after an upper thoracoplasty when the hemidiaphragm is paralysed than when it is contracting In addition, if some form of surgical apical collapse becomes necessary later, it is most desirable that the maximum function of the healthy lung tissue in the lower lobe should be preserved If good progress is made as a result of hemidiaphragmatic paralysis due to crushing the phrenic nerve, the paralysis can always be maintained by repeating the crush or by evulsing at a second operation, whereas diaphragmatic action can never be restored when the nerve has been evulsed

Indications. (1) *In pulmonary tuberculosis*—The principal use of this operation is in the treatment of pulmonary tuberculosis, as the rest and relaxation obtained assist in healing Its value is open to very great difference of opinion some phthisiologists look upon it as most valuable in a very large number of cases, whereas others consider it almost useless Its real value probably lies between these two extremes

The indications for its use are —

(*a*) When a pneumothorax cannot be induced on account of adhesions in cases with a cavity less than 2 cm in diameter and without a thick wall Temporary paralysis, which may be repeated, is preferable to evulsion

(*b*) In hæmoptysis uncontrolled by palliative methods, temporary phrenic paralysis may stop the bleeding It is usual to attempt to induce an artificial pneumothorax first, although some authorities believe that phrenic paralysis is more effective

(*c*) In conjunction with an artificial pneumothorax under the following circumstances —(i) When adhesions to the diaphragm are preventing satisfactory collapse and especially when the lung is also adherent at the apex (ii) Before allowing re-expansion of a previously grossly diseased lung the phrenic nerve should be evulsed so that the healed lung, which is of reduced size, may be able to fill the hemithorax without undue tension on the scar tissue (iii) Possibly, phrenic paralysis should be combined with all cases of pneumothorax treatment, as statistics have been produced to show that the five-year

survival rate after a pneumothorax is much higher when this is done. In addition the length of time that a pneumothorax must be maintained may be reduced and the interval between refills prolonged

(*d*) Occasionally when a patient is unfit for a thoracoplasty, the added rest resulting from a phrenic crush may produce sufficient improvement to allow the operation Preferably the diaphragm should be working again before operation

(*e*) In conjunction with intercostal neurectomy to obtain the maximum rest of the diseased lung

(2) *In diaphragmatic hernia* —In herniæ through the œsophageal

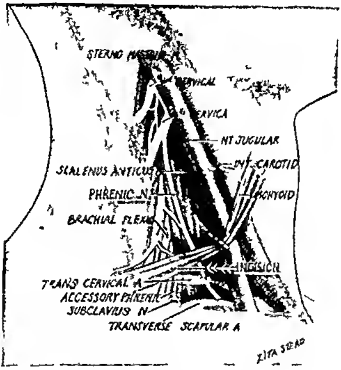


Fig 189 —Anatomy of phrenic nerve

hiatus a paralysis may be performed in cases unsuitable for a repair operation as this will prevent constriction and strangulation of the viscera When a repair operation is undertaken a preliminary crush in the neck will facilitate closure of the hernial orifice

(3) *In bronchiectasis* —Diaphragmatic paralysis is useless except in patients with residual disease in the upper lobe following lobectomy in these cases the rise in the diaphragm may diminish tension on the remaining lobe and prevent progression of the disease

(4) *After pneumonectomy*, when the pleural space has been infected and drainage employed diaphragmatic paralysis may aid in obliteration of the empyema cavity

(5) In cases of pain due to *diaphragmatic adhesions* the paralysis

should be temporary until it has been proved that the adhesions are really the source of the pain.

(6) Temporary diaphragmatic paralysis has been employed *for cases of severe persisting hiccough*.

(7) As a *preliminary to some operations* on the lower end of the œsophagus, such as resection of a neoplasm.

Anatomy.—The phrenic nerve arises from the third, fourth and fifth cervical nerves, but the contribution from the fifth root may come off lower down in the neck as a branch from the nerve to the subclavius (Fig. 189). This is called the accessory phrenic and sometimes contains almost as many fibres as the main nerve, which accounts for the considerable variation in size of the nerve. It may join the rest of the fibres in the neck but may not do so until reaching the superior mediastinum. Sometimes the main branch may be found as two separate nerves running down parallel on the scalenus anticus. The exact position of the nerve also varies considerably; it may run down the lateral border of the muscle and then cross medially at the root of the neck, but more often it crosses high up in the neck to the medial border and runs down it.

In 20 per cent. of cases paralysis is not obtained by simply cutting out a portion of the phrenic nerve. Therefore the operation of evulsion was devised by Felix of Berlin in order to pull out any accessory branches at the same time, but the same effect may be obtained if a portion of the main nerve is removed together with the accessories.

Technique for Permanent Paralysis of the Diaphragm

The patient lies on the back on a flat operating-table, the face turned to the opposite side and the assistant standing at the head of the table with the surgeon on the side to be operated on. A small sandbag should be placed under the upper part of the scapula. This allows the neck to fall backwards and brings the scalenus anticus muscle forwards, materially assisting the exposure of the nerve. The skin over the area to be incised is infiltrated with 1 per cent. novocain and a few c.c. are also injected under the deep fascia. A horizontal *incision, one inch long, is made one inch above the level of the clavicle*. The platysma and deep fascia are not divided in the line of the incision, but the muscle is split vertically in the line of its fibres by a pair of fine pointed artery forceps. This prevents not only bleeding but also subsequent widening of the scar from adhesion between the muscle and skin wounds. The scalenus anticus muscle can then be felt again with the finger as a firm band of muscle deep to the lateral border of the sternomastoid. Three small retractors are used, one in each angle of the wound and one above. The surgeon holds the outer retractor on the right side and the inner one on the left, and the assistant the other two. By blunt dissection with a pair of artery forceps, the scalenus anticus should be easily exposed. The transverse cervical vessels and omohyoid muscle, if seen, should be

retracted downwards. If, however, the surgeon sees the brachial plexus, he is too lateral; if he sees the jugular vein he is too medial. The phrenic nerve is found lying on the anterior surface of the scalenus anticus underneath the prevertebral fascia, to which it is frequently adherent, or on the medial border of this muscle. (Fig. 190.) With a small hook the nerve is lifted up and injected with 1 per cent. novocain. It is then clamped with a pair of forceps below the injected area, divided, and by steady traction and rotation of the forceps (i.e., winding the nerve on the forceps) it can be evulsed. The evulsion is the only manœuvre that causes pain. If less than 10 cm. are evulsed the paralysis may not be permanent, as the accessory

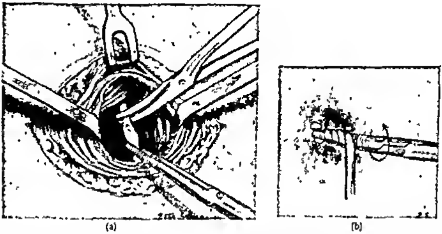


Fig. 190.—Phrenic Evulsion. (a) The phrenic nerve has been injected with novocain, is gripped by the evulsion forceps, and is about to be divided. The three retractors are shown in place. (b) Winding up the phrenic nerve on the forceps prevents the nerve slipping.

fibres may take over the full control of the diaphragm. If, on attempted evulsion, considerable resistance is encountered, it is wisest to resect as much of the nerve as possible and then remove the accessory fibres, rather than to continue pulling on the nerve until it breaks To find the accessory nerves the dissection should be continued downwards laterally (through the same skin incision), so as to expose the brachial plexus, which runs downwards and outwards from the lateral border of the scalenus anticus. From the upper trunk arises the nerve to the subclavius which incorporates the accessory phrenic fibres, when these are present; it can be seen running downwards and inwards to the root of the neck, and should be resected for 2–3 cm. The incision is closed by one No. 00 plain catgut suture for the platysma, the needle being passed from within outwards through one side of the muscle, and then from without inwards through the other, so that the knot, when tied, lies deep to the muscle. The skin may be closed by clips or, if an invisible scar is desired, by a continuous horsehair suture removed in 24 hours.

Technique for Temporary Paralysis of the Diaphragm

The preliminary steps in this operation are exactly similar to those for evulsion Having exposed and injected the main nerve with novocain the dissection is continued laterally and any accessory fibres divided This is an important step and failure to carry it out accounts for failure to obtain paralysis The main phrenic is crushed with an artery forceps but must not be severed the length of nerve crushed should only be the breadth of the blades of the forceps and the nerve should not be separated from the fascia covering the scalenus anticus as a broad crush after lifting the nerve from its bed may account for those cases in which crushing results in permanent instead of temporary hemidiaphragmatic paralysis

Intrapleural Pneumonolysis

Artificial pneumothorax frequently fails to give satisfactory collapse owing to adhesions between the two pleural layers unfortunately, these adhesions usually occur over that portion of the lung which it is most desired to collapse

The type and extent of the adhesions varies widely They are of three main kinds (1) Thin strings which stretch easily or tougher round cord like adhesions (2) Sheets and bands which may be translucent, or dense and composed of adult fibrous tissue They may be short, so that the lung is held within a centimetre of the chest-wall, or many centimetres in length and width (3) The lung may be adherent directly to the chest wall by surface adhesions over smaller or larger areas A radiogram of the chest will show the extent to which collapse is interfered with and usually gives some idea of the type and extent of the adhesions, but their real nature can only be determined by inspection Even stereoscopic films do not reveal the whole truth In some cases where a few apparently easily divided strings are seen in the film, inspection shows extensive surface adhesions in addition On the other hand, many cases which appear to be impossible in the film are found on inspection to have easily divisible adhesions

The results of artificial pneumothorax treatment have been shown *to be so much better where complete collapse of the lung is attained* that it is better to divide all adhesions when this can be done without risk It is especially important to divide any adhesion at the site of a cavity, even if the cavity has apparently closed, as in many cases the cavity has not healed and opens up again later on

Closed Intrapleural Pneumonolysis Thoracoscopy

The principle of the operation is the insertion through a rib interspace of a cannula through which the thoracoscope is passed, with this instrument it is possible to inspect the whole pleural cavity and to see adhesions as the bladder is seen through a cystoscope Various modifications of the original instrument devised by Jacobæus of Stockholm have been invented To the right angled viewing telescope has

been added one with a terminal prism which gives a forward view at 20° from the axis Through a second cannula in another interspace an electric cautery is introduced which at a dull red heat will divide adhesions under vision Or the endothermic current may be used hæmostasis is more easily attained by this but pleural effusions occur much more frequently probably as the result of a more extensive tissue necrosis

Chandler has devised an instrument which carries both the telescope and cautery and is used through a single cannula It has the dis advantage that if bleeding occurs the prism is apt to become obscured by blood and where many adhesions are present they cannot all be reached

Preoperative considerations—A long adhesion may be divided with much greater safety than a short one Although adhesions should be allowed to stretch after the induction of an artificial pneumothorax it is never justifiable to use high positive pressures to make them stretch or actually rupture this frequently causes rupture of their pulmonary attachment and a subsequent tuberculous empyema as a result of pleural infection arising from the underlying lung lesion The period which should be allowed for stretching varies in different cases several weeks or even a few months after induction of the pneumothorax are usually required but *it is unwise to continue with* an ineffective pneumothorax for many months in the hope that the adhesions will ultimately stretch sufficiently to make division possible it is better to abandon the pneumothorax and consider some other form of collapse therapy There must be a sufficiently large pneumothorax to allow the introduction of the trocar and cannula without risk of damaging the lung

Adhesions are more readily severed if fairly taut a refill of air should therefore be given on the day before operation Localization of the adhesions by stereoscopic X rays or rotating the patient under the fluoroscope is not necessary but it is essential to determine the position in which the first trocar and cannula can be inserted without damage to the lung this can usually be found by a simple postero anterior radiogram The best position for the second cannula is decided after inspection of the adhesions through the first cannula

Pleural fluid complicating a pneumothorax is not an absolute contra indication to intrapleural pneumonolysis unless it contains tubercle bacilli or is causing toxic absorption

Technique—The patient lies on the good side with the long end of the table raised so that his body is as nearly as possible vertical in this way the weight of the lung draws down the apex and renders vision easier as well as putting the adhesions under tension The under hand is put under the pillow and the upper arm is allowed to hang over the edge of the table thus pulling the scapula forward A pillow under the side curves the spine and widens the interspaces The sites for the insertion of the cannulæ must be chosen with due

regard for the position of the adhesions as seen in a radiogram but for the majority of cases the posterior cannula is inserted in the 5th or 6th interspace about an inch behind the vertebral border of the scapula and the anterior one in the axilla In cases of doubt it is best to insert the axillary one first and choose the site for the second one after inspection with the thoracoscope

At the site chosen, the skin and tissues down to the pleura are infiltrated with 1 per cent novocain, air is obtained by withdrawing the piston of the syringe if the point of the needle has passed the pleura An incision ½ in long is made in the skin and a pneumothorax needle inserted into the pleural cavity, through this a stylet two or three inches longer than the needle should be inserted If the stylet is arrested by any obstruction the site should be abandoned and a fresh one selected If no obstruction is encountered, the needle and stylet are withdrawn and the trocar and cannula introduced by a steady pressure They should not be rotated as this tends to produce a round hole in the pleura rather than a linear cut which heals more readily The trocar is withdrawn and the thoracoscope introduced The adhesions are carefully inspected, and the operator decides whether it is possible to divide them, this is largely a matter of experience it is wise to err on the conservative side Section should not be undertaken if there are yellow tubercles on the pleural surface, as a tuberculous effusion almost always results

As a general rule an adhesion should be divided close to the chest-wall, this is of the utmost importance when lung tissue extends out along the adhesion as shown by a bluish tinge If the lung tissue extends very close to the chest-wall, the safest method is to divide the parietal pleura at the peripheral attachment of the adhesion and than strip the attachment from the chest wall with the unheated cautery (Maurer s enucleation method)

Vascular adhesions may be coagulated with the flat surface of the cautery or by diathermy before cutting with the edge of the cautery loop If any vessel bleeds the bleeding point should be controlled by pressure of the cautery loop before it is coagulated by heat If this fails, then it is an advantage to have a small button cautery, which will compress the point with more certainty, and coagulate with the endothermic current

Small cords and strings often arise from the subclavian artery or the upper edge of the arch of the aorta These can be lifted away from the vessel by a cautery made in the form of a hook As the hook tends to slip towards the lung in some cases it is an advantage to use Maxwell s articulated hook, in which the cautery loop can be placed at right angles to the axis of the instrument by rotating a collar in the handle If the burning of the adhesions causes pain, the peripheral attachment of the adhesion and the pleura around should be injected with novocain through a long applicator attached to a syringe, and introduced through the cautery cannula This is always necessary if diathermy is being used, but rarely with the electro-cautery

When the adhesions are very extensive it may be necessary to stop after they have been partly divided and to repeat the operation in a few weeks time This is particularly useful for short adhesions in the region of the subclavian artery as these will lengthen owing to the weight of the lung which then depends on them

Where a bilateral pneumothorax is present the patient sometimes becomes so dyspnœic on introducing the cannulæ that the operation is not possible If a pneumothorax needle is introduced and attached to a suction pump the patient is rendered comfortable and the operation can proceed

At the end of the operation any small pool of blood which may be seen should be aspirated by a suction tube This blood has usually trickled along the cannulæ from the chest wall If left it excites a pleural effusion

The stab incisions are sutured and a pad fixed tightly with adhesive strapping to prevent surgical emphysema If there is any shortness of breath the pressure is adjusted by removing air with a pneumothorax apparatus

Postoperative care —The patient should be nursed in a sitting up position for a few days and not allowed to lie down even for a few minutes This is to prevent any fluid entering the upper part of the chest First because if strands of fibrin are formed attached to the lung and chest wall new sheets and cords may be formed and secondly as the fluid always contains tubercle bacilli on culture it is inadvisable to allow it to infect the wounds made by the cannulæ

The chest should be X rayed the following day and subsequent refills of air controlled by the degree of collapse found Effusions are more frequent if the pressures are raised too much at first Small r refills at more frequent intervals are more satisfactory Any blood or effusion which collects in the pleural cavity should be aspirated and replaced with air

Open Intrapleural Pneumonolysis

This operation is very rarely if ever indicated When the adhesions are divisible by the closed method the open technique which involves opening the pleural cavity and dividing the adhesions under direct vision should never be performed as the incidence of massive post operative effusion empyema loss of the pneumothorax space and re-attachment of the adhesions is greater The operation may be justifiable in an occasional case of bilateral disease in a patient unfit for thoracoplasty when it is imperative to obtain an effective pneumothorax but adhesions indivisible by the closed method are preventing it.

When adhesions are indivisible by the closed method their position is noted the usual site is in the apical region more frequently posterior than anterior Hence a posterior incision through the upper part of the chest usually gives the best exposure

Technique —Local anæsthesia is preferable but nitrous oxide and oxygen may be used The exposure is obtained exactly as in extra

pleural pneumonolysis except that the incision in the fourth rib bed is carried through into the pleural cavity for a length of 3½ in. If thoracoplasty has shown an adhesion with its peripheral attachment in this position, the fifth rib or another in this region should be taken instead. The pleural cavity is inspected with a light on a long malleable stalk. A vascular string or cord adhesions may be divided close to the chest-wall attachment, with scissors. All other types, especially broad short vascular bands, should be "enucleated" by dividing the peripheral pleura at the base and stripping the attachment from the chest-wall in the extrapleural plane; any bleeding that is caused should be controlled with the electro-cautery, diathermy or by ligature.

The wound is closed as described under extrapleural pneumonolysis, except that the sutures in the rib bed include the pleura. It is even more important after intrapleural pneumonolysis that this suture line should be air-tight, as a frequent cause of failure is escape of air and loss of the pneumothorax space or re-attachment of the divided adhesions. The postoperative treatment is similar to that after the closed technique.

Extrapleural Pneumonolysis

This operation gives a selective pulmonary collapse by stripping the parietal pleura from the chest-wall and mediastinum over the diseased area and filling the extrapleural space thus obtained with some substance. If air is used to maintain the space, i.e. the operation is done to obtain an extrapleural pneumothorax, the separation should be as extensive as necessary to obtain and keep any desired amount of pulmonary collapse; this may require separation down to the diaphragm. When the space is filled with a solid or semi-solid substance such as paraffin wax (autogenous fat or muscle grafts have also been used), the operation is limited almost entirely to the closure of cavities in the upper third of the lung, as the danger of perforation of wax into the lung when more than 400 grammes are used is much increased. Air as a filling has the advantages over wax that the extent of the collapse can be controlled to a certain degree after operation, and that wax cannot perforate into the lung or externally. Extrapleural pneumothorax is therefore to be preferred to pneumonolysis with "plombage."

This form of collapse therapy is not so satisfactory as thoracoplasty, but is useful when the patient is unfit for thoracoplasty on account of the activity of the lesion, or bilateral disease or some factor complicating the pulmonary tuberculosis such as cardiovascular insufficiency.

Technique.—Local or general anæsthesia may be used, but the latter causes less discomfort. Cyclopropane or nitrous oxide are the best forms of inhalation anæsthesia; the former has the advantage that respirations are very shallow, so that there is minimal lung movement during the extrapleural separation, but has the disadvantage

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that being inflammable diathermic coagulation cannot be used for hæmostasis inside the chest

A posterior incision should always be used With an anterior or axillary approach it is very difficult to maintain the pneumothorax and wax almost always gradually comes out into the subcutaneous tissue

The patient lies on the good side with the uppermost scapula elevated and rotated as far forwards as possible This position brings the vertebral border of the scapula to overlie and run parallel with the third intercostal space so that the posterior part of the fourth rib is no longer covered by it A 5 inch incision is made over the fourth rib the inferior fibres of the trapezius divided at the medial end and the rhomboid major split in the line of its fibres (Fig 191) The

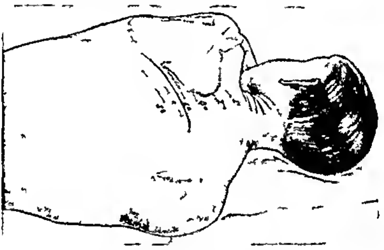


Fig 191 —Incision for extrapleural pneumonolysis

serratus posticus superior is separated from its attachment to the fourth and fifth ribs and retracted A 5 inch segment of the fourth rib is subperiosteally resected extending back to the transverse process

To expose the plane of the endothoracic fascia which consists of a little connective tissue between the parietal pleura and the chest wall the intercostal muscles are carefully divided until the pleura is seen There is less risk of opening the pleura by this method than by incising the periosteal bed of the portion of rib removed With the finger the pleura is carefully detached all round the wound until there is a sufficient extrapleural space to continue the separation under direct vision The upper margin of the periosteum and adjacent intercostal muscles are retracted with two small double hook retractors A light on a malleable stalk is held in the artificially-created space by an assistant while the operator holding the lung down by a small gauze swab on a holder continues the separation of the pleura under vision or by means of another such swab or by a special metal spatula Along

the posterior ends of the ribs and over the bodies of the vertebræ the pleura is usually more adherent in these regions it is preferable to use the finger for stripping Bleeding may occur from vessels in the chest-wall, particularly in the neighbourhood of the internal mammary vessels and at the posterior ends of the intercostal spaces Sometimes an intercostal artery or nerve is stripped down with the pleura, if it cannot be separated from the pleura, it must be ligated and divided Great care is taken to leave the walls of the extrapleural

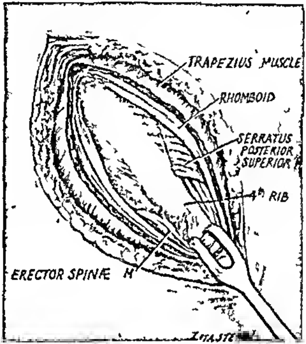


Fig 192 —Anatomical details of posterior end of fourth rib

space as dry as possible any bleeding points in the chest wall are coagulated with the diathermic current if a non inflammable anæsthetic is being used, if the anæsthetic gas is inflammable, hæmostasis is obtained with ligatures or neural clips No coagulation should be done on the pleura itself

If the extrapleural pneumonolysis is being performed for the induction of an extrapleural pneumothorax it is important that the pleura should be stripped down to the hilum on the mediastinal surface, down to the eighth or ninth rib posteriorly, and anteriorly to at least the third or fourth costal cartilage This allows for partial re expansion of the lung, which always follows the operation Failure to close pulmonary cavities is usually due to inadequate separation

If the operation is done to maintain apical collapse by "plombage," the extent of the separation must be much less owing to the small amount of wax that can be safely used Although some surgeons

have claimed better results from leaving the medial apical and mediastinal portions adherent in order that the paraffin wax may compress the diseased apical part of the lung against the mediastinum the best results are probably obtained by separation of the apex in its entire circumference as for extrapleural pneumothorax

The paraffin must be chemically pure with a melting point of 45° C It is sterilized by heating at 150° C for one hour The paraffin may be introduced into the cavity with a Tudor Edwards paraffin syringe which has a water jacket which keeps the wax soft Or the wax may be poured out into a sterile bowl and when it is beginning to set be compressed into small pieces about the size of a walnut which are packed into the cavity The wax in the chest must be snugly pressed together so that no air spaces exist

The incision in the intercostal muscle and rib bed is repaired with a continuous No 2 chromicized catgut suture this should be done with great care in order that air may not escape from an extrapleural pneumothorax and wax may not be extruded when plombage is employed The extracostal muscles are likewise sutured and the skin approximated with an unabsorbable suture A pneumothorax needle is then inserted and a refill of 200–400 c c of air is given until the pressures are just positive before the patient leaves the operation table

Immediate after-treatment —The patient is kept sitting up A second refill is given some six or seven hours later a third after another twelve hours and then daily refills for a few days

A radiogram is taken on the day after operation and about every third day for the next fortnight The spacing and pressures of subsequent refills are decided by the radiographic appearance and the rate at which the pressure falls between the refills An attempt is made to keep the pressures at +14 to +20 It is very important that the lung should be kept down from the very beginning as if it expands in the first few hours it may be impossible to obtain a good collapse again Increasing the pressures and decreasing the interval between refills has a good effect

All cases show a small fluid level by next day At first these were left alone but now as a routine the fluid which is usually pure blood is aspirated and if it recurs aspiration is repeated at a few days interval until it no longer recurs During this time the sitting position is maintained in order that bands of fibrin may not form in the upper part of the cavity they might by their organization subsequently draw out the lung

Postoperative complications of extrapleural pneumothorax — 1 *Hæmorrhage* —This may be a slow oozing which gradually fills up the space It should be removed by suction with the aid of a thoracoscope any clot being broken up by the metal suction tube This should be done early or it may not be possible to remove the clot

In some cases serious delayed hæmorrhage occurs after 48 hours Copious blood transfusion should at once be given The blood should not be removed for some days

2 *Late effusion* —In a high proportion of cases clear effusions begin after some months and eventually turn into tuberculous pus Late infections with streptococci have occurred after many weeks

3 *Emphysema* —There is always a little subcutaneous emphysema, less on the whole than in thoracoscopy It may extend to the neck and cause a little discomfort in swallowing

4 *Contralateral disease* may increase

There is no doubt that postoperative morbidity is higher than in thoracoplasty and the operative mortality is no lower Churchill has pointed out that if the lung does re expand it does so at the expense of the diseased part of the lung The indications for the operation are therefore few It should in my opinion be reserved for cases where, owing to the condition of the patient, thoracoplasty is inadvisable and thoracoplasty should be done after the patient has improved

THORACOPLASTY

Indications —This operation is rarely if ever, indicated for pulmonary disease other than tuberculosis In bronchiectasis and chronic lung abscess its value has proved to be transitory or negligible and surgical excision of the diseased area has entirely replaced collapse therapy The modified form of thoracoplasty for chronic pleural suppuration has already been considered (*See* p 315)

In pulmonary tuberculosis, thoracoplasty in its modern form has proved to be one of the most satisfactory methods of collapse without carrying undue risk to the patient Follow up study of tuberculous patients treated by collapse therapy has shown that there is less likelihood of re activation of the tuberculosis after thoracoplasty than after temporary forms of collapse such as pneumothorax Nevertheless the operation should only be undertaken after careful consideration of each individual patient by one experienced in the selection of cases after consideration of the following points —

(1) *Age* —The best results have been obtained in patients between 30 and 40, patients under 30 have on the average less resistance to the disease than those of the fourth decade The hazards of the operation become progressively increased after the age of 40, nevertheless good results may be obtained up to the age of 60 No patient therefore between 20 and 60 in whom the operation is indicated should be refused on account of age alone

(2) *General condition* —An ambulant patient in whom the general cardio vascular tone has been maintained is a much better risk than a patient who has been confined to bed for a long period An estimate of cardio respiratory reserve must be based on dyspnœa and cyanosis, the pulse rate at rest and after walking exercise, the blood pressure the amount of chest expansion and the vital capacity or lung volume Clubbing of the fingers suggests superadded broncho-pulmonary suppuration and is usually a warning against thoracoplasty

(3) *Type and distribution of the disease* —Patients with unilateral disease will obviously give the best results, however bilateral disease

is not necessarily a contra indication and thoracoplasty may even be combined with some form of selective collapse on the opposite side such as a pneumothorax The pulmonary lesion should be in the productive or fibrotic phase i e the patient should be showing some attempt at spontaneous healing by fibrosis ideally there should be evidence of contraction of the fibrous tissue shown by shift of the mediastinum narrowing of the interco tal spaces or rise of the diaphragm Although thoracoplasty is primarily designed to close cavities in fibro cavernous tuberculosis a certain amount of associated infiltrative disease is not necessarily a contra indication

Examination of serial radiograms taken during an essential pre operative period of sanatorium treatment is of the greatest value in determining the type of disease present Further information about the activity of the lesion must be obtained from the general appearance of the patient temperature chart erythrocyte sedimentation rate and differential white blood count

(4) *Suitability for other forms of collapse* —In general only patients in whom intrapleural pneumothorax has been attempted without success should be treated by thoracoplasty However where the cavernous lesion is restricted to the apex of the upper lobe on one side there is a growing tendency to perform a partial thoracoplasty with apicolysis without first attempting an artificial pneumothorax on the grounds that the operative mortality is very low and the patients return to work within a year avoiding the necessity for keeping a pneumothorax for several years and then being faced with the difficulty of terminating it

General principles of the operation —The operation has the common object of all forms of collapse therapy—cavity closure with preservation of the maximum amount of healthy lung When the disease is spread throughout one lung the whole of that side must be collapsed by removal of the ribs down to and including the 10th or even 11th ribs But when it is limited to the upper portion as so commonly happens it is only necessary to collapse the upper affected part leaving the lower part to carry on its normal respiratory function it is in these cases that the modern upper selective thoracoplasty has entirely replaced the old Sauerbruch complete paravertebral operation

The collapse provided should not be in one plane only but concentric towards the hilum It is for this reason that the vast majority of thoracoplasties should be combined with apicolysis which involves freeing the apex from its attachments at the root of the neck thus allowing shrinkage in the vertical as well as the horizontal plane This important addition to thoracoplasty has been popularized by Holst and Semb

Maximum collapse of the diseased area must be obtained at minimum risk to the patient The operation is therefore divided into stages as it has been found that if no more than three ribs are removed at a single stage the risk is very small whereas removal of more involves

an increased risk proportionate to the number removed The stages should always be arranged from above downwards, the first stage, therefore, being removal of the upper three ribs

To obtain adequate collapse, the whole of the 1st rib, together with part of its cartilage, the whole of the 2nd with its cartilage, and the major portion of the 3rd rib (in each case, excluding the head and neck which lie medial to the transverse process) must be removed Below this, the length of each rib removed is graded according to the extent of collapse required From the third rib downwards it is necessary in some cases to remove the transverse processes and adjacent portions This should be done where a radiogram taken before the second stage of the operation shows that a cavity is under or in close proximity to the processes Usually, sufficient lengths of ribs may be removed from behind through a parascapular incision but with giant cavities an antero lateral stage for removal of the anterior stumps remaining after completion of the posterior stages may be necessary

Pre operative preparation.—All patients should have a period of sanatorium treatment before operation The duration depends on the activity of the lesion when the patient comes under care If the disease is already in the fibro-cavernous stage and showing little evidence of activity, a few weeks only are required When activity is more marked a longer period is required but it must be emphasized that all patients will not ultimately arrive at the ideal stage of a purely fibro cavernous lesion simply by waiting the likelihood of spread before operation increases proportionately with the time allowed to elapse before collapse therapy is undertaken As soon, therefore, as the patient ceases to show definite improvement, operation should be undertaken if there is still an active lesion, the amount done at each stage must be limited accordingly

Occasionally, when rest alone does not produce improvement, the addition of *temporary* phrenic paralysis may do so, by this means a few patients in whom thoracoplasty would not at first appear justifiable owing to the risk involved may be rendered suitable for the operation It is wise, however, to have the diaphragm contracting again before proceeding

During the 48 hours immediately before operation glucose by mouth should be given to the limit of tolerance 4 drachms of 50 per cent glucose in lemonade given four hourly are usually quite acceptable

Anæsthesia.—Cyclopropane is the best anæsthetic available, it allows adequate oxygenation and quiet respiration, which are desirable if bronchogenic spread is to be avoided, the quiet breathing also reduces the technical difficulties of apicolysis Nitrous oxide and oxygen with the addition of a *little* chloroform when necessary, may be used if an anæsthetist experienced with cyclopropane is not available Local anæsthesia has given good results in experienced hands but is a long and tedious manœuvre and trying to the patient

Position on the table.—The patient lies on the good side with a rubber cushion under the middle of the thorax so that the uppermost intercostal spaces are widened The legs are placed as in the 'kidney position,' the upper straight and the lower flexed The upper arm is drawn forwards and supported by a nurse who sits opposite the patient's face The patient is prevented from rolling forwards by a special padded support which is attached to the operating table The table is tilted into a 15° Trendelenburg position so that any secretion expressed by collapsing the lung may gravitate down the trachea into the mouth rather than into the opposite lung The

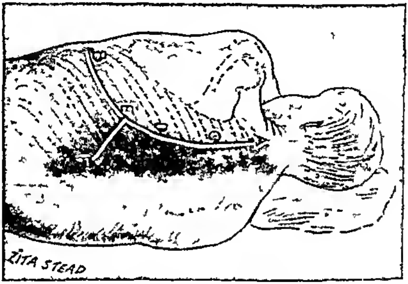


Fig 193 —Incision for two upper stages of thoracoplasty, and crosscut for lower stage

patient should be arranged in the position for operation before being anæsthetized A catheter is placed in the rectum so that 1 000 c c of 5 per cent glucose in tap water at 110° F may be run in after the incision has been made and the ribs exposed, this decreases the shock resulting from elevation of the periosteum and helps to replace fluid lost from the circulation by hæmorrhage

First stage operation—A J shaped incision is made the vertical part commencing on a level with the seventh cervical spinous process (which usually corresponds to a point about 1½ in below the superolateral border of the trapezius) and running vertically downwards 1 in medial to the vertebral border of the scapula, it curves forward about 1½ in below the inferior scapular angle almost to the mid axillary line (Fig 193) The extracostal muscles are divided in the same line as the skin incision thus exposing the chest wall The assistant manually raises the vertebral border of the scapula from the chest wall the costal surface of the serratus anterior is exposed by division

with scissors of a little loose connective tissue between the scapula and the chest wall A pair of blunt pointed scissors is insinuated into the interval between the upper three digitations of serratus anterior and those below and the interval widened by separation of the scissor blades so as to allow the passage of a finger anterior to the upper three digitations with the index finger of the left hand in this position so as to protect the axillary structures the upper fibres are divided with scissors at their costal origin (Fig 194) The scapula can then be further elevated from the chest wall

A small incision is made along the lateral border of the sacrospinalis

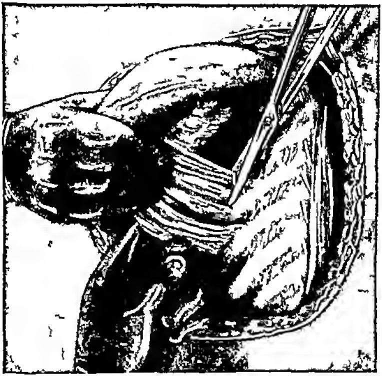


Fig 194 First stage thoracoplasty D v s on of the serratus anterior

so as to separate it from the third rib and the muscle retracted with two small hook retractors by a second assistant the periosteum of this rib is divided longitudinally from the tip of the corresponding transverse process forwards almost to the costal cartilage Working backwards along the lower border and forwards along the upper border the periosteum is stripped from the external surface and two borders of the rib with a Farabeuf s rugine a Doyen s raspatory is carefully insinuated around the rib in its posterior part and the periosteum stripped from the internal surface by sweeping the raspa tory forwards The rib is divided with shears posteriorly on a level with the tip of the transverse process and again anteriorly near the

costal cartilage, and removed The second rib is removed in an exactly similar manner, except that the division anteriorly should be actually at the costo chondral junction and not merely close to it

The first rib is removed after removal of the third and second ribs The outer border can then readily be felt but rarely seen Having defined the outer border by palpation the fingers of the left hand are placed immediately below it and an incision is made through the muscles and periosteum covering the outer border in its posterior part The periosteum is elevated from the outer border and inferior surface with a rugine With the rib thus exposed to view, the peri

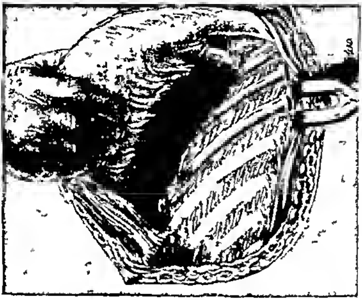


Fig 195—Resection of first three ribs completed

osteum is elevated from its upper surface with a special angulated rugine from behind forwards Special care should be taken to avoid injury to the subclavian vessels the first thoracic nerve and the lower trunk of the brachial plexus, which are all in direct relation to the first rib if the rugine is kept strictly subperiosteal, there is no likelihood of damage to these structures The inner border is cleared with a special hook shaped raspatory If the rib is divided posteriorly flush with the transverse process and grasped with bone forceps, the periosteal and perichondrial separation of the extreme anterior end of the rib and the lateral part of the costal cartilage (which part should also be removed) may be made easier by depressing the rib The rib is finally removed by division of the costal cartilage immediately lateral to the attachment of the costo-clavicular ligament (Figs 195 196)

Since vertical as well as horizontal collapse is desirable in order to obtain closure of apical pulmonary cavities the apex of the lung should be released from its attachments to the neck and mediastinum

in most if not all cases To do this the apex of the lung covered with the periosteum of the first three ribs and the intervening intercostal bundles is depressed with the left hand this brings into prominence certain bands of fibrous tissue anchoring the lung to the root of the neck these bands have been defined by anatomists and each labelled according to its position in practice these fibrous attachments appear to vary somewhat in position although two are usually found posteriorly adjacent to the first thoracic nerve (Fig 197) All such bands are divided after ascertaining that no important structure is incorporated only those that bleed after division are clamped and ligated The apex is thus entirely liberated Separation from the mediastinum is accomplished by wiping the parietal pleura away with a gauze sponge held in forceps The apex is further mobilized by clamping dividing and ligating the first, second and third intercostal bundles close to where the ribs have been divided posteriorly (Fig 196) The first and second intercostal structures should be treated likewise anteriorly By this means, the apex can

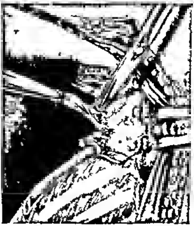


Fig 196 —Removal of intercostal bundle

Fig 197 —Division of extrapleural fascial bands

be readily depressed to a horizontal plane on a level with the posterior end of the unresected fourth rib (Fig 198) After the wound is closed, there is a large space above the lung containing air and blood-stained serum which are very gradually absorbed This, however does not result in re-expansion of the lung as the periosteum which remains attached to it re forms bone, thus anchoring the lung down in its new position

Much stress has been laid by some authors on the distinction between extrafascial and extrapleural apicolysis such distinction appears largely theoretical provided the periosteum and intercostal

Fig 198 —First stage completed

structures are not stripped off the lung The separation from the mediastinum is invariably extrapleural

Finally, the extracostal muscles are approximated with a continuous No 2 chromicized catgut suture and the skin with a continuous unabsorbable suture No drainage is employed A dressing is applied and, with a cotton wool pad in the axilla, the chest is firmly strapped with adhesive strapping in order to prevent paradoxical movement during respiration

Second stage operation—There are very few cases in which sufficient collapse is obtained by the first stage operation The extent of further rib resection must be decided from careful consideration of radiograms taken before and after the first stage As a general rule, it is necessary to extend the decostalization down to

include one or sometimes two ribs below the lowermost limit of any cavitation present owing to the oblique course of the ribs the posterior ends are on a much higher horizontal plane than the anterior ends, it is, therefore, the posterior segments of the ribs which must be considered in relation to any cavities present

The *interval* between the *first and second and subsequent stages* varies with the individual case but is ideally between three and four weeks If the patient is not fit to undergo another operation at the

Fig 199 —Second stage thoracoplasty The scar tissue over the extrapleural space formed at the first operation is seen above the fourth rib

end of this period, the next stage must be delayed The anæsthesia, position on the table, and method of reducing shock by rectal fluid are similar to those of the first stage The previous skin and extra-costal muscle incision is re-opened, with the exception of the upper two inches The scapula is raised by an assistant, and adhesions which have formed between it and the chest-wall are broken down manually This allows adequate exposure of the fourth and lower ribs down to the eighth Working from above downwards, decostalization is carried out in a manner exactly similar to that in which the third rib was removed at the first stage (Fig 199) By retracting

the semispinalis muscle each rib is divided posteriorly flush with the tip of the transverse process If the transverse process is to be removed the tendinous attachments to the tip of the process are snipped with scissors and the rest of the process cleared with the rugine If a pair of bone-cutting shears with the blades at right angles to the shaft is used the transverse process and rib can be cleanly divided at one cut The position of division anteriorly depends upon the size and distribution of cavities present large cavities and those seen to extend anteriorly in a lateral radiogram require removal

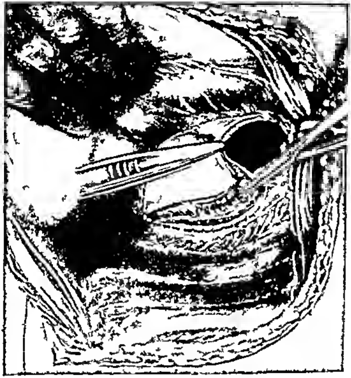


Fig 200 Resection of ribs completed Scar tissue is being removed.

of long lengths of the ribs when there is no very large cavity and the cavitation is confined to the upper half of the lung posteriorly the point of division anteriorly is graded from above downwards in an average case $\frac{3}{4}$ of the fourth rib $\frac{2}{3}$ of the fifth and $\frac{1}{2}$ of the sixth (and $\frac{1}{3}$ of the seventh when necessary) are removed the removal of segments of four ribs is justified when long lengths are not excised and when the anæsthetist is of the opinion that the patient's general condition has not deteriorated during the removal of the fourth fifth and sixth ribs

When this decostalization is completed the fibrous tissue septum which separates the present operative field from the apical pocket filled with blood-stained serum resulting from the first stage apicolysis

is divided by an incision parallel with and external to the previously resected third rib (Fig 200) Finally the fourth intercostal bundle is clamped divided and ligated and the lung freed from the posterior mediastinal gutter in this region by separation with a finger (Fig 201)

The wound is closed without drainage as in the first stage and the chest again strapped firmly to prevent paradoxical movement

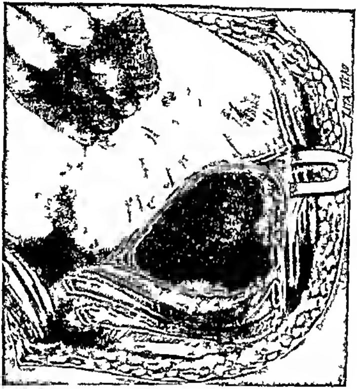


Fig 201 —Operation completed The freeing should be prolonged much further forwards than is shown in the diagram

Third and subsequent posterior stages —Further decostalization must be controlled entirely according to the collapse necessary to close any residual cavities The lower ribs are best exposed by opening up the lower half of the old wound in addition an incision at right angles to this is made running downwards and backwards through the skin and extracostal muscles this T shaped incision gives good exposure and obviates any possibility of gangrene of the corners of the flaps thus marked out Removal of the ribs is carried out exactly *as before* if *complete* collapse of the whole lung is required the decostalization must extend down to and include the tenth or eleventh rib The wound is closed as before

Antero-lateral thoracoplasty —Occasionally in the presence of very large apical cavities adequate collapse is not obtained by rib removal through the posterior incisions described above In such

cases the remaining anterior stumps should be removed by an antero lateral operation. The objection to this procedure is the deformity it produces, the patient being left with a large hollow in the subclavicular region. If radiograms taken two weeks after completion of the posterior stages show persistent cavitation, the antero lateral operation is indicated. It is unwise to delay longer to see if the cavitation will subsequently close, because the upper ribs are meanwhile stiffening by regeneration of bone and the additional collapse obtained by an antero lateral stage done later will be much less.

Technique.—The patient lies flat on the back with the arm on the affected side held in abduction by an assistant who can rotate and manipulate it during the operation so as to slacken the pectoral muscles. An oblique 6 in. incision extending down from the apex of the axilla is made parallel with and immediately behind the lateral border of pectoralis major. This muscle is retracted forwards and medially so that the anterior rib ends are exposed. The periosteum is elevated with a rugine and the anterior segments removed; part of the corresponding costal cartilages may be excised together with the ribs when very extensive anterior collapse is required. The wound is closed without drainage by approximation of the skin incision. Great care must be taken to stabilize the chest wall by firm strapping, as the anterior part of the chest is unprotected by the scapula and when flail allows gross paradoxical movement.

Secondary operations.—Failure of cavity closure by thoracoplasty has very much decreased since apicolysis has been combined with the majority of thoracoplasties. Those cases collapsed by the old technique with persistent cavities should be re-operated on and apicolysis performed after removal of re formed bone. There are, however, a few cases in which cavitation yielding a positive sputum persists even after combining apicolysis with decostalization. These require re operation and removal of re-formed bone in the region of the radiologically-demonstrable cavitation. The old posterior incision is re opened and the periosteum separated from those ribs which appear to be preventing closure of the cavities. As the re-formed ribs are very irregular, this procedure is often difficult, always tedious and shocking to the patient; the amount done at one operation should therefore be limited.

Postoperative care.—In spite of the most careful hæmostasis a patient with large muscles loses a considerable quantity of blood during the operation. It is a great aid to quick and uneventful convalescence if a blood transfusion is given at the end of the operation. Certainly one patient in three requires blood. The transfusion should be about 500–600 c c given by the drip method. A litre of 5 per cent glucose in normal saline given intravenously gives rapid replenishment of the circulating fluid if a blood transfusion is not available. If the patient is cyanosed or if there is any degree of dyspnœa oxygen

should be given Cyanosis is not seen if the hæmoglobin percentage is low, although the patient may be needing oxygen

A postoperative sedative for pain is required, but this must not diminish the cough reflex dilaudid gr 1/32–1/48 relieves pain to the same extent as morphia with less effect on the cough centre The patient is encouraged to expectorate all sputum, expectoration is facilitated if the nurse applies firm pressure with her hand against the decostalized chest-wall To prevent stagnation of sputum the patient should not be allowed to lie for long periods in one position but must lie on the back and on the side operated on alternately every two hours If the sputum is tenacious steam inhalations and ammonium chloride (gr x four hourly) by mouth help to loosen it Secondary anæmia resulting from blood loss at the time of operation should be treated by giving iron (pulv ferri redact grs xx t d s) by mouth The firm strapping applied at the time of operation should be maintained during the first week if paradoxical movement is minimal when the strapping is removed, it may be left off altogether Various methods of increasing by compression the collapse obtained by thoracoplasty have been employed one of the most satisfactory is to make the patient lie on the operated side with a folded pillow in the axilla, the patient's own weight thus provides the compression This "pillow treatment" should commence one week after operation, at first, it will only be tolerated for about one hour on end

The patient is usually fit to get up on the tenth to twelfth day Finally, it must be impressed on the patient that thoracoplasty is not a cure for pulmonary tuberculosis but only a mechanical procedure that puts him in a better position to cure himself, and the operation must always be followed by at least six months' sanatorium treatment

Intercostal Neurectomy

This operation is performed for two main purposes (*a*) The relief of pain caused by extensive trauma to the chest-wall that has involved the intercostal nerves or pain due to an old pleurisy (*b*) John Alexander has advocated it in certain cases of pulmonary tuberculosis After paralysis of the diaphragm by phrenic evulsion, the costal movements are somewhat increased to compensate, but if an intercostal neurectomy is added there will be complete immobilization There are cases of unilateral tuberculosis where pneumothorax is impossible owing to adhesions, and a thoracoplasty is indicated but the patients are too ill for it In these cases, the condition may be improved by absolute immobilization on the affected side, and may thus be better prepared to stand the thoracoplasty at a later date

Severe pain due to infiltration of intercostal nerves by growth extending from the lung or primary pleural endothelioma is best relieved by a posterior rhizotomy rather than intercostal neurectomy

Technique.—The operation is performed under local anæsthesia A vertical incision is made over the lateral border of the erector spinæ muscle, the superficial muscles are divided, the ribs exposed opposite

the angles and the intercostal nerves found by incising the external intercostal just lateral to the angle. The second to the tenth inclusive are exposed, injected with novocain and an inch of each nerve resected. If the lower two thoracic nerves are left intact there will be no subsequent weakness of the abdominal wall.

SCALENOTOMY

This, like the preceding operation, is employed in pulmonary tuberculosis when it is desired to obtain the maximum rest on the affected side. The operation was suggested by Drs Gale and Middleton of Madison, Wisconsin in 1931, after extensive research. The efficiency of the intercostal muscles in elevating the ribs depends on the fixation of the first rib by the scalene muscles. Therefore they resect these muscles at the same time as the phrenic evulsion when they wish to paralyse the diaphragm for a lesion in the upper third of the chest. They are also performing this operation in conjunction with a neurectomy of the upper six intercostal nerves. It is carried out through the incision for the exposure of the phrenic nerve, but it is continued backwards until the anterior border of the trapezius is exposed. Through this opening all three scalene muscles can be divided at their insertion into the first rib.

The operation has few indications, and is rarely performed.

III. DIAPHRAGMATIC HERNIA

Hernia of the abdominal viscera into the pleural cavity or into the mediastinum may occur through openings due to embryonic deficiency, in which case the opening is at certain definite sites, or through openings due to trauma which may occur at any point in the diaphragm. The hernia is most commonly on the left side, as the large bulk of the liver usually occludes right-sided openings. However, they do occur on the right side, and I have operated on two such cases. The contents of the hernia are most frequently the omentum, stomach, small intestine, colon and spleen.

Symptoms.—The symptoms which draw attention to the condition are most often abdominal. They are pain, vomiting and symptoms of obstruction. They may be almost entirely gastric and lead to the diagnosis of gastric ulcer, which may indeed exist in the thoracic portion of the stomach. Strangulation, leading to gangrene of the intestine or colon, is usually fatal even with operation. Thoracic symptoms such as pain, pain in the shoulder, dyspnœa and cyanosis are uncommon compared with the abdominal symptoms. A boy who had had symptoms of obstruction for four days at the age of 11 again got obstruction at the age of 19. A week before he had won a four-mile race, yet at operation the spleen, the whole of the stomach and omentum, most of the small intestine and the colon, with cæcum and appendix, were found in the pleural cavity.

Diagnosis—The diagnosis rests on demonstration of viscera in the thorax by X rays preferably after a barium meal The examination should be done with the patient supine and the foot of the table raised Eventration of the diaphragm which is much less common than hernia may cause difficulty but usually the opaque meal shows narrowing of a hollow viscus as it passes through the hernial orifice

Treatment—Diaphragmatic hernia should be treated by operation In *symptomless cases discovered during an X ray examination* and in cases without severe signs of obstruction or strangulation the operative mortality is almost nil Where obstruction has been present for several days the mortality is higher In strangulation it approaches 100 per cent *It is reasonable therefore to operate even* when symptoms are few or absent as sooner or later obstruction or strangulation will occur

Pre-operative treatment—The passage of a stomach tube will deflate the distended stomach If serious vomiting has occurred the patient is dehydrated and has lost essential salts He is probably suffering from acidosis Several litres of normal saline with the addition of calcium lactate sodium bicarbonate and glucose should be given *intravenously* by the *drip method* *Ringer s fluid* is better but is difficult to sterilize and is rarely available If mild symptoms of obstruction only are present an enema may be given

Operation—Herniæ through the œsophageal hiatus are best dealt with by an abdominal approach (*see* Vol II) For all others the transpleural route is best The diaphragm is completely exposed and intrathoracic adhesions can be easily and safely divided In some cases an ulcer of the stomach has been found adherent to the pericardium and was dealt with by this route Where adhesions to the abdominal side of the opening are present the ring may be enlarged by incising the diaphragm if necessary In my experience it has never been necessary to do a combined laparo thoracotomy

A long *intercostal incision* in *the 6th or 7th interspace* (*see* major thoracotomy page 328) gives the best access The viscera present are identified and if the stomach is distended a tube is passed to empty it Any adhesions—which are usually only omental—are divided There are usually adhesions at the lips of the orifice and these are carefully separated a finger passed into the abdomen as soon as a portion of the ring is cleared will help in defining the muscular edge by putting the adhesions on the stretch If there is a peritoneal sac which is rare this is also divided at the ring The viscera are then returned to the abdomen an enlargement of the opening being made if necessary A pad of gauze or rubber is then tucked into the abdomen to retain the viscera At this point it is well to pinch the phrenic nerve with a narrow bladed artery forceps close to the diaphragm to produce a temporary diaphragmatic paralysis If the margins of the opening are thick and solid they can be closed by mattress sutures of No 2 10 day chromic catgut withdrawing the

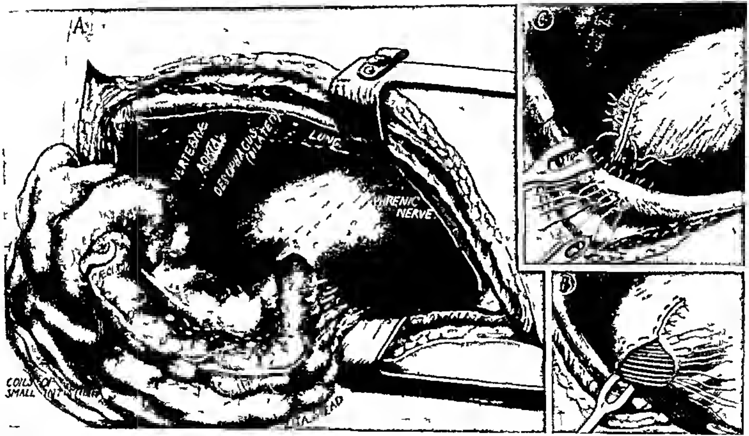


Fig 202 —Diaphragmatic hernia

(a) Structures exposed by long intercostal incision. (b) Interrupted mattress sutures being inserted, a gauze pack protecting abdominal contents. (c) Second layer of interrupted sutures in diaphragm, and mattress sutures [illegible] to chest wall

abdominal pad before tying the last sutures A second row of sutures takes in the free edge (Fig 202) Where the opening abuts on the chest-wall there is sometimes a gap This can be closed by sutures passing through the diaphragm and chest-wall In some cases it may be necessary to resect a short length of two or three ribs, to mobilize the chest wall, so that there is no great tension on these sutures

In some cases the tissues around the opening may be little more than a layer of thin fibrous tissue Here it is better to discard catgut and use fascial strips, plicating the paralysed diaphragm as much as is necessary It is bad practice to attempt to close the opening by suturing the stomach or other viscus in it After closing the incision in the chest wall, air should be withdrawn from the pleura by a pneumothorax needle and box leaving a negative pressure of not more than −5 cm of water

Postoperative treatment.—A pleural effusion almost always occurs and should be aspirated from time to time It should be examined bacteriologically each time and if infection—which is rare—is present, the pleura should be drained

IV. OPERATIONS ON THE HEART

Aspiration of the Pericardial Sac

This may be required for the removal of a large serous effusion that is embarrassing the heart, or for the confirmation of the diagnosis of suppurative pericarditis before pericardiotomy

Technique.—Local anæsthesia is employed The site of puncture is in the angle between the costal margin and xiphisternum on the left side The needle should be of large gauge with a tip that has only a slight bevel, it is introduced upwards, backwards and slightly outwards, suction being maintained all the time, as it should only just enter the pericardial sac If cardiac rhythm is transmitted to it, its point is in or touching the heart wall and must not be pushed any further.

Pericardiotomy

The site for drainage is not so important as in a pleural empyema, because once the pericardium has been opened *all* fluid is pumped out by the heart action

Dependent drainage was first advocated by Allingham in 1900, through an extraperitoneal epigastric approach This is a blind procedure, as the pericardial sac cannot be inspected, and a very simple operation may become an abdominal one with the added risk of infecting the peritoneum

Technique.—Local anæsthesia is employed An incision is made down the left side of the sternum, and the fifth and sixth costal cartilages and intercostal muscles are resected The costo mediastinal sinus of the pleura has usually been pushed aside or obliterated by the

dilated pericardium but care should be taken not to open the pleura The internal mammary vessels are ligated the triangularis sterni is divided and the pericardium picked up with forceps and opened with a knife by a vertical incision Immediately the pus is squirted violently out by the cardiac and respiratory movement Drainage is best obtained by suturing the cut margins of the pericardium to the deep fascia on no account should rubber tubes be used inside the pericardium The pericardium should never be irrigated with Dakin s solution Claude Beck of Cleveland Ohio has demonstrated by experimental work on dogs that this fluid causes severe pericarditis

Pericardiectomy and Cardiolysis

In cases of adherent pericardium two different anatomical states must be recognized although they are often combined in the same patient —

(1) Obliteration of the pericardial sac with imprisonment of the heart by an adherent parietal pericardium In severe cases the patients present all the signs of cardiac failure but without enlargement of the heart The pathological physiology of this condition is based on impairment in the filling of the heart produced by a snugly fitting thickened pericardium which also prevents the negative pressure of inspiration from helping to fill the right auricle The treatment for the relief of this condition is the removal of the anterior part of the pericardium or pericardiectomy (Delorme s operation)

(2) Adhesion of the parietal pericardium to the chest wall preventing recession of the pericardium with the ventricular systole and in consequence causing embarrassment of cardiac action This condition is relieved by decostalization of the chest wall overlying the heart so as to permit it to move with the pericardium (Brauer s cardiolysis) The operation usually performed for adherent pericardium is a combination of pericardiectomy and cardiolysis but the two operations will be described separately

Pericardiectomy.—The patient is placed in a semi recumbent position on the operating table A semicircular incision is made from the anterior end of the third rib above down the middle of the sternum and along the costal margin below The pectoralis major muscle is reflected with the skin The fourth fifth and sixth costal cartilages are entirely resected with their corresponding intercostals The mediastinal structures are then separated from the sternum by blunt dissection and two-thirds of the sternum removed for a length of three inches The anterior margin of the pleura can then be seen and is displaced laterally by blunt dissection with scissors and gauze The pericardium is incised down to the heart muscle and a line of cleavage sought and the thickened parietal pericardium separated by blunt dissection first from the left ventricle and then from over the right and base of the heart Care should be taken to separate the phrenic nerve from the left side of the pericardium By this dissection it should be possible to resect the pericardium from the whole of the

anterior and lateral surfaces of the exposed heart One or both pleural cavities may be opened during the operation This is not important if the anæsthetic is being given by intratracheal tube The anæsthetist distends the lungs at the end of the operation by positive pressure If a small tear is made in the pleura it may be repaired by suture, but there is possibly some advantage in allowing the blood-stained exudate which always follows to drain into the pleural cavity, from which it can readily be aspirated At the end of the operation the musculo-cutaneous flap of chest wall is sutured in two layers without drainage

Cardiolysis.—A large semicircular incision is made starting from the second rib above and running down the mid line of the sternum and following the costal margin below The overlying muscles are reflected laterally with the skin flap, and the costal cartilages and lateral half of the sternum exposed The second to seventh costal cartilages and, in addition, one inch of the bone of the fourth and fifth ribs are then resected subperiosteally, and the lateral half of the sternum is nibbled away over the exposed area with rongeur bone forceps To prevent *regeneration of bone the periosteum is painted* with Zenker s solution The musculo cutaneous flap is then sutured in two layers, with a small drainage tube into the wound for 48 hours

Decompression of the Heart

In certain cases of enlarged heart, especially in children with definite precordial bulging associated with heart failure that will not respond readily to medical treatment, a deliberate decompression of the heart may be perfomed The technique is exactly similar to that for cardiolysis, and the results are excellent

Penetrating Wounds of the Heart

In penetrating wounds of the heart which are not immediately fatal, the patients may die from tamponade due to compression of the heart by the collection of blood in the pericardial cavity On examination there may or may not be external bleeding from the injury, the patients are shocked, with a weak or imperceptible pulse, but not necessarily of an increased rate, and the area of cardiac dullness is *considerably enlarged When an implement or foreign body showing* cardiac movement projects from the chest wall it should not be withdrawn until the heart has been exposed by operation

Operation for suture of the heart wall.—Anæsthesia may be local or general A flap of skin and muscle from the second to fifth left costal cartilages is turned laterally If the left pleura has already been opened by the injury, the pericardium may be exposed by an intercostal incision with division of the cartilages at the sternum and forcible spreading of the ribs, but in the absence of pleural injury the heart is exposed by resection of the third, fourth and fifth cartilages and intercostal structures The internal mammary vessels must be ligated, the pleura carefully retracted laterally, and then the peri

cardium incised The blood in the pericardium may project the heart forward through the opening and as pointed out by D C Elkin of Atlanta if the wound can be seen it should be sutured before the pericardial sac is decompressed because then the heart starts to beat violently the wound bleeds and the difficulty of suturing is considerably increased Blood escaping from the heart wound is controlled by placing the index finger over the opening and the heart is steadied by a temporary suture passed through the apex While the finger controls the bleeding a suture of No 1 silk on a curved needle is passed through the heart wall underneath it and tied as the finger is withdrawn additional sutures may then be passed if required. Whenever possible the sutures should avoid entering the heart cavity All the blood is carefully removed from the pericardium The sac is only partially sutured so that the effusion which develops may escape into the surrounding tissues and the musculo-cutaneous wound is closed with a small drainage tube going down to the pericardium.

V OPERATIONS ON THE CHEST-WALL

Excision of Tumours of the Chest Wall

These tumours arise from the bone or cartilages of the chest wall About 60 per cent prove to be sarcoma 20 per cent chondroma and among the remainder many are osteoma In a series of 218 collected cases Hedbloom of Chicago showed that 78 7 per cent involved the ribs and 21 per cent the sternum Sarcomas especially if they are large should be treated by X rays before excision and for rapidly growing sarcomas of the chest wall in children this is probably the only justifiable treatment Secondary malignant growths are best left alone but a metastatic hypernephroma in a rib should be excised if no other secondary growth can be found as these metastases are sometimes single Where a carcinoma of the upper lobe of the lung has invaded the chest wall a wide resection of the chest wall with the upper lobe in one piece can be done Although the growth may return in the mediastinum the patient is relieved of the pain which is often severe and very distressing With these exceptions all tumours of the chest wall should be excised

Principles of operation —Anæsthesia is by gas and oxygen with a well fitting mask so that positive pressure may be applied if necessary

It is usually impossible to excise a tumour of the rib without removing a portion of the parietal pleura and if several ribs are involved there will be a considerable deficiency in the chest wall The incision should therefore be so planned that the line of suture does not lie over the deficiency a horseshoe-shaped incision is usually the most satisfactory The overlying muscles are reflected with the skin flap and the tumour freely excised When the pleura is opened the collapse of the lung is prevented by positive endopharyngeal pressure Attempts at closure of the deficiency in the chest wall by

shuffling the ribs or suturing the lung to the margins are not successful, but if the musculo cutaneous flap is drawn over the deficiency and carefully sutured in layers it suffices to cover the gap A pad and firm dressing is then applied with adhesive, and postoperative coughing should be prevented by sedatives

After this operation a pleural effusion usually develops, and may require to be removed by aspiration

Tumours of the sternum are treated on the same principle by wide excision

CHAPTER IX

OPERATIONS ON THE SPINAL CORD

By LAMBERT ROGERS

LYING in the sagittal plane near the centre of axis of rotation of the vertebral bodies and covered posteriorly by the bony neural arches and their overlying powerful muscle masses, the relatively small spinal cord is well protected from injury

The cord, however, is otherwise highly vulnerable inasmuch as it represents, as it were, a "bottle neck" of concentrated nervous pathways leading from the relatively massive brain to the extensive periphery, so that a comparatively trivial injury to it, whether produced by external violence or by pressure from a new growth, may result in widespread paralysis Furthermore, there is no regeneration of divided pathways in the human cord and thus it follows that, from the nature of its protection injuries of the spinal cord produced by violence are, fortunately relatively uncommon, but when they do occur are likely to be both catastrophic in type and disastrous in effect

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

Surgical anatomy. **Landmarks of the spine** —The tips of the spinous processes may readily be identified by palpation, the most prominent is that of the 1st thoracic vertebra, but the uppermost spine to form a

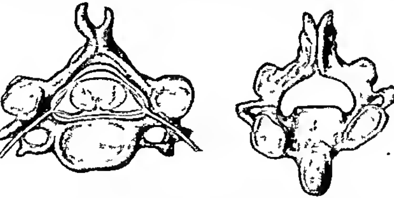


Fig 203 —Cervical vertebra from above with cord *in situ* and axis from above showing facets in front of the neural grooves

visible projection is usually the 7th cervical (so called "vertebra prominens") except when the neck is flexed, when the 6th cervical spine may come to the surface The root of the spine of the scapula normally lies opposite the 3rd thoracic spinous process while its inferior angle is at the level of the 7th thoracic spine The highest

part of the iliac crest constitutes a very constant landmark being on a level with the upper edge of the 4th lumbar spine or the space between this and the next spine above

Vertebral column—In the *cervical* region the spinal canal is relatively wide and there is a considerable space between the cord and its bony surroundings The cervical vertebræ are characterized by the presence

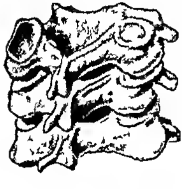


Fig 204 —Cervical vertebræ from behind

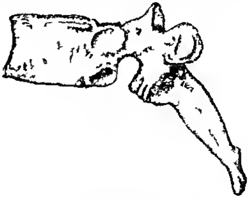


Fig 205 —Dorsal vertebra from side

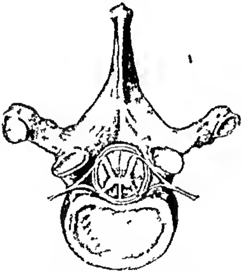


Fig 206 —Dorsal vertebra from above with cord *in situ*

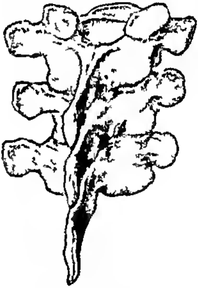


Fig 207 —Dorsal vertebræ from behind

of the foramen for the vertebral artery and its accompanying vein and sympathetic nerve fibres This artery represents a preneural post costal anastomosis (T Yeates) and thus lies in front of the issuing nerves The typical spinous processes are bifid This is the most mobile part of the column and the plane of the articular facets is almost horizontal The superior articular facets in the axis and atlas lie in front of the neural grooves but in the remainder of the cervical vertebræ are placed behind them (Figs 203 204)

In the *thoracic* region the spinal canal is relatively narrower so that there is less space between the cord enclosed in its meninges and its bony surroundings the laminæ are relatively broader than in the cervical region and more closely approximated to each other and the spinous processes are long and obliquely placed The articular processes lie in a plane which is almost vertical and the upper ones look backwards and outwards Because of the dorsal convexity of the spinal column in this region and the fact that here the post vertebral grooves are relatively shallow and the erector spinæ muscle mass is flattened and tendinous this part of the spinal canal is the most readily accessible to the surgeon (Figs 205 206 207)

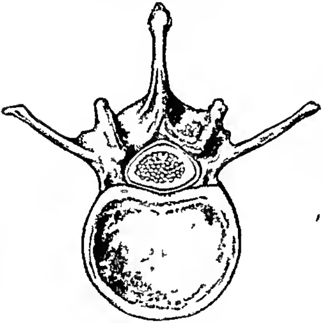


Fig 208 —Lumbar vertebra from above with cauda equina *in situ*

Fig 209 —Lumbar vertebræ from behind.

In the *lumbar* region the spinal canal again becomes relatively large in comparison with the space taken up by the cord and its membranous coverings while the individual vertebræ are altogether more massive and the vertebral grooves deeper owing to the greater development of the erector spinæ muscle mass The spinous processes are stout and project almost horizontally backwards in contra-distinction to the obliquely placed spines of the cervical and thoracic vertebræ The articular processes are vertically placed and the upper ones look inwards and firmly interlock with the inferior facets of the vertebra above so that little or no rotary motion is possible in this part of the column This part of the spinal canal is the most deeply placed and least accessible (Figs 208 209)

The intervertebral discs —These consist of upper and lower plates of cartilage with the annulus fibrosus and the nucleus pulposus (remains

of notochord). The discs give mobility to the spinal column without impairing its strength. If either cartilage plate is damaged or the annulus fractured, a herniation of nuclear material may take place. This extrusion of disc substance may give rise to symptoms.* (See p. 405.)

Spinal meninges.—The spinal *dura mater* is a fibrous tube which extends from the edge of the foramen magnum to the second sacral vertebra. It contrasts with the corresponding cranial membrane in being much less intimately related either to its bony surroundings or to its neural contents, since posteriorly it is separated from the neural arches by an *epidural* space, while it forms but a loose sac around the cord. Below the level of the foramen magnum the dural tube is unattached posteriorly. It is attached to the bone around the foramen magnum and, by means of the filum terminale, to the back of the coccyx with which it fuses where it is closed below; elsewhere the dura is loosely adherent anteriorly to the posterior longitudinal ligament, and the anterior and posterior nerve roots carry with them tubular prolongations which blend with the periosteum at the margins of the intervertebral foramina. Because of its close relationship with the backs of the bodies of the vertebræ, which approximates it to the centre of rotation of the column, and because of its freedom from attachment posteriorly, the dural tube containing the spinal cord obtains the utmost freedom from interference by movements taking place in the vertebral column. The healthy spinal dura is a bluish pulsating tube covered posteriorly by a thin layer of pale epidural fat. On either side of the mid-line lie the posterior longitudinal veins, from which fine tributaries arise and anastomose with one another.

The *spinal arachnoid* is directly continuous with that within the cranial cavity and is a filmy and transparent membrane. If the dura is carefully opened so as not to damage the arachnoid, the cord, bathed with cerebro-spinal fluid, may be seen through it. Filmy strands connect the arachnoid with the pia. Small white calcareous or bony plaques occur not infrequently in the spinal arachnoid. Like the dura, it gives a sheath to the issuing nerve roots.

The *subarachnoid space*, containing the cerebro-spinal fluid, is continuous above with the cerebro-spinal fluid reservoirs within the skull and is closed below at the level of the upper border of the 2nd sacral vertebra. The cord itself terminates as the conus medullaris (terminalis), below which is a large pool of cerebro-spinal fluid (lumbar pond) which bathes the cauda equina and the filum terminale. It is this pond of cerebro-spinal fluid which is tapped by the lumbar puncture needle (Fig. 210). In the adult the conus lies at the lower border of the 1st lumbar vertebra, but in early fœtal life the cord occupies the whole spinal canal and at birth extends as low as the 3rd lumbar vertebra. For this reason the conus medullaris may be damaged by lumbar puncture performed on an infant.

* Alajouanine et Petit Dutaillis, *Pr. Med.*, 1930, xcviii, 102; Mixter and Barr, *New Eng. Journ. Med.*, 1934, cxi, 210, early drew attention to such lesions.

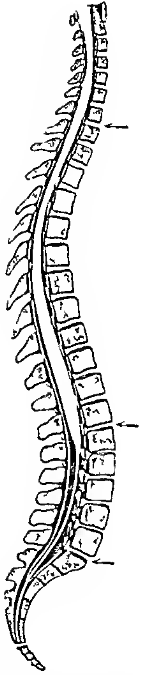


Fig 210 —Extent of dura arachnoid and cord

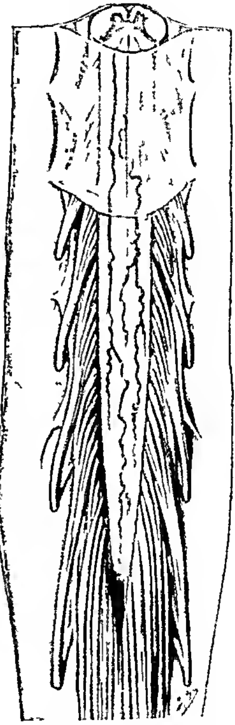


Fig 211 —Ligamentum denticulatum and fork. (After Elsberg)

The *pia* over the spinal cord is thicker and stronger than the corresponding membrane of the brain. It is beset with fine vessels, and sends septa into the anterior fissure and the posterior median sulcus of the cord. Anteriorly it thickens to form a glistening band (linea splendens), which is continuous below with the filum terminale.

The *ligamentum denticulatum* attaches the cord to the dural tube. It consists on either side of 20-22 triangular slips which lie between the anterior and posterior nerve roots and pass from the pia to the dura, to which each slip is attached by its apex midway between the openings in the dura for the passage of the individual nerves (Fig 211). The lowest denticulation is fork shaped instead of triangular and is crossed by the first lumbar nerve.*

The spinal cord.—Somewhat flattened anteroposteriorly in the cervical region, the cord elsewhere has a circular cross section. As the issuing nerves are given off from it the amount of white matter which it contains decreases so that this is relatively less in amount in the lower than in the upper parts of the cord (Fig 212). The cord extends from the margin of the foramen magnum to its conical termination at the level of the lower border of the 1st lumbar vertebra and at the sites of origin of the limb plexuses presents expansions (cervical and lumbar enlargements).

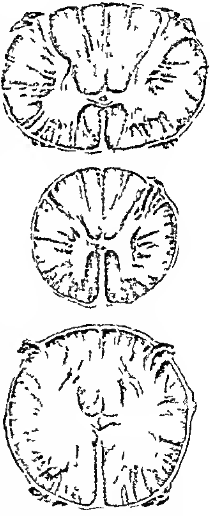


Fig 212.—Transverse section of cord at cervical dorsal and lumbar levels

The *cervical enlargement* occupies the upper part of the cord and extends down to the 2nd thoracic vertebra attaining its maximum girth at the level of the 5th or 6th cervical vertebra. The *lumbar enlargement* begins at the level of the *10th* dorsal vertebra and attains its maximum development opposite the 12th, and below this rapidly tapers into the conus medullaris.

The level of particular segments within the cord.—The cord being shorter than the spinal canal, the segmental nerves have an oblique intraspinal course between their origins and the intervertebral foramina through which they leave the

* Elsberg, Diseases of the Spinal Cord and its Membranes, N. Y., 1916

canal The length of the intraspinal course of the nerves progressively increases from above downwards (Fig 213) Although there is a certain amount of variation the following statements are sufficiently accurate to be of practical value *

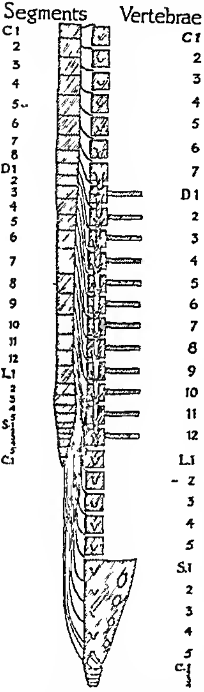


Fig 213 Relation of vertebræ to segments

(a) The intraspinal course increases fairly regularly for the cervical and thoracic nerves It is about equal to the depth of one vertebra for the upper cervical and of two vertebræ for the lower cervical of three vertebræ for the upper six thoracic and of four vertebræ for the lower six thoracic (Thus the 10th thoracic segment would correspond with the 6th thoracic vertebra)

(b) The origins of the lumbar nerves (segments) are opposite the 10th and 11th thoracic spines

(c) The origins of the sacral nerves (segments) are opposite the 12th thoracic spine and the interspinous ligament between it and the 1st lumbar spine

The nominal relationship of nerves and vertebræ changes at the 8th cervical nerve above this the nerve issues above the vertebra of the same name below this level the nerve issues below the vertebra of the same name

The nerve roots —Each of the 31 pairs of spinal nerves arises from the side of the cord by two roots anterior and posterior of which the posterior root is the larger except in the case of the suboccipital nerve the posterior root of which is sometimes absent Both roots arise from the cord by fasciculi but whereas those comprising the posterior roots enter the cord consecutively along a continuous straight line at the bottom of a slight furrow those giving origin to the anterior roots arise somewhat irregularly from the antero-lateral sur

* Medical Research Council Rept 11 Injuries of the Spinal Cord and Cauda Equina, 1924

face of the cord and from an area of some breadth (Fig 211) The ganglia which lie upon the posterior roots just before their union with the anterior roots to form the issuing spinal nerves for the most part occupy the intervertebral foramina

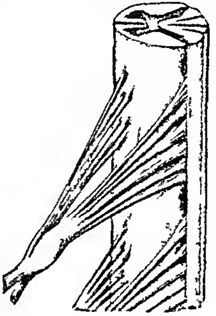


Fig 214 —The anterior and posterior nerve roots

Blood supply of meninges and cord Arteries —Spinal arteries enter the spinal canal through the intervertebral foramina and give off three sets of branches (i) *prelaminar* to the deep surface of the neural arches (ii) *neural* which pierce the dura immediately above the site of exit of the corresponding spinal nerve and (iii) *postcentral* which pass inwards to the back of the vertebral bodies and give off ascending and descending branches which anastomose with corresponding branches from the arteries above and below In the cervical region the spinal arteries arise from the vertebral in the thoracic and lumbar regions from the dorsal branches of the intercostal and lumbar arteries respectively Twigs also enter the spinal canal in the cervical region from the ascending cervical branch of the inferior thyroid artery and in the sacral region from the lateral sacral artery A large number of tortuous small arteries may be seen ramifying in the pial covering over the surface of the cord These arise from five longitudinal trunks one of which is the anteromedian artery while the other four are postero laterally placed lying in the sulci in which the posterior nerve roots enter the cord and being related to the anterior and posterior aspects of the line of posterior roots These longitudinal trunks are connected above with the anterior and posterior spinal branches of the vertebral artery and anastomose with the branches which enter with the nerve roots

Veins —The veins of the cord are small numerous and tortuous but for the most part form longitudinal trunks which ramify on the anterior and posterior surfaces of the cord and in relation to each set of nerve roots The state of the veins which run longitudinally on the back of the cord is sometimes helpful to the surgeon in enabling him to decide whether a laminectomy is above or below a site of cord compression because the veins below the site are prominent and congested while those above appear normal The veins of the spinal canal are large and complex in their arrangement but for the most part form anterior and posterior plexuses related respectively to the backs of the vertebral bodies on either side of the posterior

common ligament and to the deep surfaces of the laminæ and ligamenta subflava Wide channels pass through these ligaments to connect with dorsal spinal venous plexuses in the vertebral grooves Branches also traverse the intervertebral foramina to join the posterior branches of the intercostal and lumbar veins At the base of the skull the venous plexuses enter the basilar and occipital sinuses and give off branches which emerge above the neural arch of the atlas to form the origin of the vertebral vein

The cerebro-spinal fluid is formed by the choroid plexuses in the cerebral ventricles and in normal subjects its total quantity is from 110 150 c c Fluid produced by the plexuses of the lateral ventricles enters the 3rd ventricle through the foramen of Monro on each side and is here added to by that produced by the plexus of this ventricle It flows backwards through the Sylvian aqueduct into the 4th ventricle where it is again added to by the plexus here and in addition to filling the ventricle occupies the central canal of the cord Leaving the 4th ventricle through the large median foramen of Magendie and the laterally placed foramina of Luschka it fills the basal cisterns and traverses the cranial and spinal subarachnoid spaces It is absorbed by the arachnoidal villi into the intracranial venous sinuses The production passage and absorption of the fluid has been termed the third circulation (Harvey Cushing)

Spinal shock is the phase of suppression of function in that part of the cord suddenly isolated from the rest of the central nervous system It is thought to be due to a sudden interruption of impulses passing down the cord and not to a general depression in vitality consequent upon the injury This is supported by an observation of Gordon Holmes that in a unilateral lesion of the cord spinal shock may be confined to the injured side Its duration varies considerably both in animals and man but in human adults may last 7 10 days or longer During this period reflex activity is absent except in those parts which are supplied from the most caudal segments of the cord thus following a high thoracic transection there is complete flaccid paralysis below the level of the section and retention of urine and fæces but after a week or ten days when spinal shock has passed off reflexes return and retention is no longer complete small quantities of urine may now be expelled from the bladder and a reflex type of micturition come about so that it discharges itself at intervals

The bladder —This automatic bladder is an excellent example of how smooth muscle adapts itself to carry on its original functions after the loss of its extrinsic nerve supply The fluid content sufficient to excite the local vesical emptying reflex varies *within rather wide* limits but is usually somewhere about 300 c c The automatic action may be hampered in cases in which the motor nerves (nervi erigentes S 2 S 3 occasionally S 4) or their centres of origin have been damaged while the hypogastric *inhibitory* nerves *from* the lumbar sympathetic ganglia are left intact This may occur in crush or other injuries of

the conus medullaris when improvement may follow presacral sympathectomy which by lessening sphincter tone and by withdrawal of the inhibitory impulses to the bladder muscular tone assists the establishment of the automatic action (*See* Surgery of Sympathetic Nervous System Vol II)

Care of the bladder in paraplegic cases —Infection occurs much more readily in an over distended bladder with a stretched musculature than in one in which muscle tonus has been maintained and the mucosa protected from the stretching which interferes with its blood supply Distension therefore should be prevented either by frequent catheterization by the use of an indwelling catheter or by establishing a suprapubic cystostomy When repeated catheterization is carried out this must be gently and carefully performed because injury however slight like overstretching is conducive to infection An indwelling catheter with an apparatus to effect tidal drainage has proved effective. Hexamine and sulphonamides should be administered (*see also* p 423)

Conduction in the cord —The position of the chief conducting tracts is shown in Fig 215 Once transected regeneration does not occur in

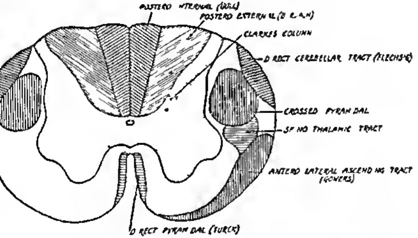


Fig 215 – Transverse sect on of sp nal cord showing chief motor *and sensory tracts*

the human cord and all attempts to suture divided cords have proved futile Although regeneration occurs in fish and amphibians e g the lopped off tail of the newt is reformed and with it the terminal part of its cord in mammals there is no satisfactory evidence of regeneration either in fœtuses or adults * Although when completely severed the cord lacks the power of regenerating it may yet be compressed to a surprising extent and recover its function when the compression is relieved This power of recovery is greatest in children and young adults (Wilfred Trotter) I have recorded a case in which the cord was so flattened by a tumour as to resemble a piece of tape but the patient a girl aged 16 who was completely paraplegic and incontinent

* See D Hooker *Journ Comp Neurol* 193? lxi 277

at the time of removal of the tumour, had within four months fully recovered both sensation and motor power, as well as control of the sphincters *

Elsberg† has pointed out that the more peripheral dermatomes are represented in the cord by tracts which lie external to those arising from more central dermatomes, and it is therefore sometimes possible to differentiate pressure from without the cord (e g extramedullary tumour) from pressure from within the cord (e g intramedullary tumour) since in the former case there is a progressive march of symptoms from the periphery towards the trunk, i e symptoms appear in the foot before the thigh

PUNCTURES OF THE MENINGES

Spinal Puncture

This may be undertaken for diagnostic or therapeutic purposes or for inducing anæsthesia Puncture is most often performed in the lumbar region where the lumbar pond of fluid is tapped and in the suboccipital region, where the cisterna magna (cerebello-medullaris) is entered Lumbar puncture as we know it to day dates from 1891, when it was first carried out by Heinrich Quincke of Kiel, while cisternal puncture was first performed in 1908 by Alexandru Obregia of Bucharest ‡ but was not adopted as a routine procedure until 1919, when Wegeforth Ayer and Essick carried it out in the United States and published details of their method of performing it ||

Indications.—Spinal punctures are made to obtain cerebro spinal fluid for chemical cytological and bacteriological examination, for the measurement of the fluid pressures, as a means of draining the subarachnoid spaces for the introduction of therapeutic substances, for the introduction of air either for the purpose of investigation or in order to break down arachnoidal adhesions and open up the fluid path ways for the introduction of radio opaque oils to ascertain the condition of the spinal subarachnoid space radiologically and for the induction of spinal anæsthesia (*see* p 393)

Dangers and complications. Damage to cord and infection —If incorrectly performed the cord itself or the medulla at the cistern may be *damaged and hæmatomyelia and interference with conduction* result meningitis *may* occur if aseptic precautions are not fully observed and it should be remembered that the cerebro spinal fluid, unlike the blood is devoid of antibodies

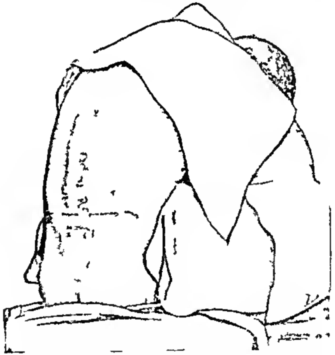
Damage to intervertebral discs —If the needle point traverses the dural tube and enters an intervertebral disc a fissure may *be produced* in the annulus through which nuclear material may subsequently herniate § (*See* p 406)

* *Brit Journ Surg* 1927 28 xv 675 *Lancet* 1935 i 187
† *Rep Ninth Congr Soc Internat Chirurg Madrid* 1932 p 385
‡ La Rach centese sous-occip tale, *Comp Rend Soc. Biol* 1908 lxv 277
|| *Amer Journ Med. Sci.*, 1919 clvii, 789
§ Pease *Amer Journ Dis Child* 1935 xlix 849

Medullary compression—In cases of internal hydrocephalus and raised intracranial pressure (e g such as may result from a tumour in the posterior fossa) in which there is herniation of the cerebellar tonsils through the foramen magnum the withdrawal of fluid by lumbar puncture may by reducing the content of the water-cushion below the tonsils permit further herniation and a sudden fatality may take place from medullary compression The danger of lumbar puncture in cases of high intracranial pressure (i e cases with highly choked optic discs) cannot be overstated

Headache —Deviations from normal intracranial pressure either in a positive or negative direction may result in headache and the lowering of pressure following spinal puncture may be followed by troublesome headache which persists for some time This can often be relieved or avoided altogether by lowering the patient s head and giving a large quantity of water to drink Acetylsalicylic acid is a useful analgesic

Technique —*Lumbar puncture* may be carried out either with the patient seated (Fig 216) or lying on the side the left lateral position



F g 216 —S tting pos t on for lumbar puncture

is the one usually adopted (Fig 217) The needles in use vary and may be of either the coarse or gentil type or adapted to fit a manometer (Figs 218 219 220) The spine should be arched backwards so as to open the interlaminar spaces this is effected by flexing the patient s head and thighs as much as possible It should be remembered that provided the subarachnoid space is not obstructed

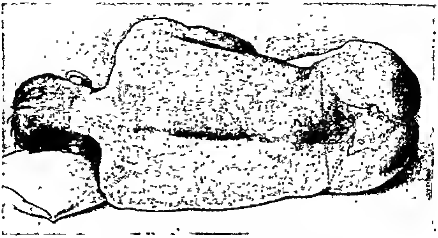


Fig. 217.—Left lateral position for lumbar puncture.

the pressure of the fluid in the lumbar pond will vary with the level of the patient's head in relation to that of the pond.

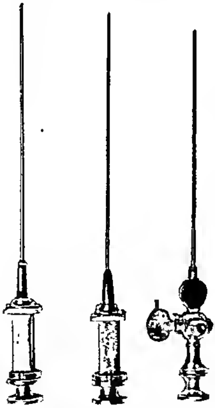


Fig. 218.—Lumbar puncture needles. Needles of a much finer calibre are also used.

The skin of the lumbar region having been carefully sterilized, that point is noted at which a line connecting the highest parts of the iliac crests crosses the line of the vertebral spines. This point may conveniently be found by using the edge of a sterile towel stretched across the spine from the maximum point of convexity of each iliac crest. It lies either over the 4th lumbar spinous process or the interspace just above this process, i.e. between L.3 and L.4. This particular space may be selected or the one above, i.e. between L.2 and L.3, since in either case the needle will enter the lumbar pond below the conus medullaris. A wheal of local anæsthetic should first be made with a very fine and well-sharpened hypodermic needle. Through this wheal more anæsthetic is injected along what is to be the course of the spinal needle. The spinal needle should be entered directly in the midline, midway between the spinous processes, and kept strictly in the sagittal plane, with its point

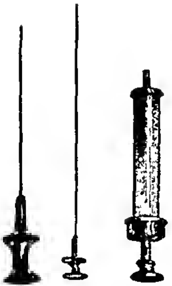


Fig 219 —Syringe and needles used in spinal puncture

directed slightly towards the head If the point is felt to strike a lamina, its direction must be changed, still keeping the needle shaft strictly in the sagittal plane, however, so that the point penetrates the ligamentum subflavum between the laminæ At a depth of approximately 1 cm beyond the ligament, the point of the needle is felt to be free and, on withdrawal of the stylet, fluid escapes in drops

Lumbar puncture presents few difficulties, but in some cases there is a failure to withdraw the fluid This generally means that the needle has passed alongside and not penetrated the dura In these circumstances a few drops of blood may escape owing to injury to one of the veins If this occurs, it is preferable to withdraw the needle, wash it with sterile saline solution and re-insert it If the needle strikes bone, and it is not possible to make it slide over its edge, it is also better to withdraw and re-insert it With the spine horizontal, the head in the sagittal plane and the patient breathing quietly, *the normal pressure* of fluid in the lumbar pond is approximately 120 mm of water Coughing straining and pressure on the great veins at the root of the neck normally cause rises in the pressure Jugular compression normally causes a rapid rise to 300 mm or more of water (Queckenstedt phenomenon) *

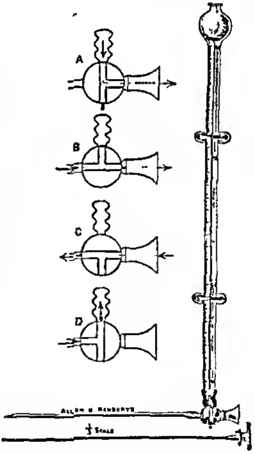


Fig 220 —Greenfield's manometer for measuring the pressure of the cerebrospinal fluid.

Cisternal Puncture

This may be carried out with the patient lying in the lateral

* Zur Diagnose der Rückenmarkskompression *Dtsch Z Nervenheilk* 1918 lv, 325

position, but is most conveniently performed when he is seated with his head facing directly forwards, *i e in the midline, but flexed* so that the chin is on the chest while an assistant stands in front and steadies the head in this position (Fig 221) The hair has first been shaved off the back of the head and the skin of this region and of the back of the neck has been sterilized An ordinary lumbar puncture needle is used, and is passed so that *the point enters in the middle line* midway between the posterior arch of the atlas and the under surface of the occipital bone The needle point is directed upwards until it strikes the under surface of this bone and then with the point against the bone and

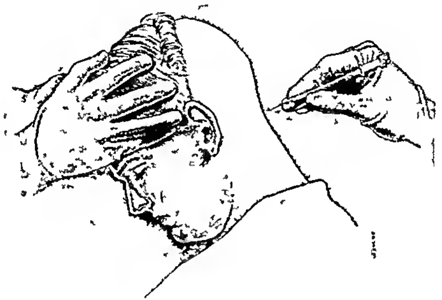


Fig 221 —Cisternal puncture In practice the face is shut off by a sterile towel.

strictly in the middle line it is slowly passed forwards until it is felt to penetrate the posterior occipito atlantal ligament (Fig 222) The stylet should be withdrawn a small syringe attached to the needle and the plunger of the syringe withdrawn because the fluid in the cistern when the patient is in this position is at a pressure slightly below atmospheric and does not therefore always well out spontaneously when the cistern is entered With the technique described the needle enters the cistern at its widest part immediately below the posterior margin of the foramen magnum At this site the needle point is usually separated from the medulla by a distance of about 2 cm

In cases of suspected spinal compression 1–2 c c of heavy lipiodol may be *introduced through the needle* into the cistern and the patient subsequently X rayed to ascertain whether the oil blob is arrested during its course through the subarachnoid space towards the lower limit of the meninges (Plate II facing p 249)

Alcohol Injections by Spinal Puncture for the Relief of Pain

In 1931 A. M. Dogliotti,* of Turin, suggested the use of intrathecal injections of absolute alcohol as a means of alleviating intractable pain. Such a simple procedure is of a comparatively minor character compared with chordotomy (p. 402) or rhizotomy (p. 401), and if safe and effective would have much to recommend it. Alcohol has a lower specific gravity than cerebro-spinal fluid, and by placing the subject in a position in which the posterior roots were uppermost, it was hoped that it would be possible to attack the posterior roots while leaving the anterior unaffected. Care being taken to avoid injury to the cord, a small lumbar-puncture needle is used to inject 0.2–1 c.c.

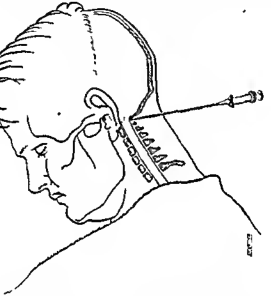


Fig. 222.—Cisternal puncture. Diagram showing the point at which the needle should penetrate the dura mater.

of absolute alcohol in the vicinity of the roots conveying the painful impulses, the patient lying prone and being kept in this position for at least ten minutes after the injection. In a few patients symptoms may be relieved almost at once, in others within a few hours, but paraplegia has followed in some cases and little or no relief of pain in others. Sphincter disturbances, manifested by retention or incontinence of urine or fæces, may also occur but have usually disappeared within a fortnight. The procedure must be described as uncertain in its results and fraught with the possibility of unpleasant complications. Chordotomy or rhizotomy are more accurate and more certain.

Investigation of the Subarachnoid Space in Suspected Spinal Cord Compression

There are two methods of investigating the condition of this space: (1) by means of physical and chemical changes in the cerebro-spinal

* Pr. méd., xxxix, 1249.

fluid (2) by radiography after the introduction of innocuous opaque substances Chemical examination of the fluid obtained by lumbar puncture will show whether there is evidence of lumbar stagnation the chief indication of which is increase in the protein-content without cellular proliferation while the Queckenstedt phenomenon—the effect of jugular compression upon the pressure of the cerebro-spinal fluid in the lumbar pond—will enable inferences to be drawn as to the presence of complete or partial obstruction to the space (spinal block) (Fig 223)

The chief contrast media to be used in the spinal subarachnoid

A B C

Fig 223 —The Queckenstedt phenomenon. The arrows indicate the onset and release of jugular compression.

A normal pressure wave Free circulation of cerebro-spinal fluid in the subarachnoid space B complete spinal block C incomplete spinal block—a rapid rise has occurred but because of partial obstruction the curve shows a flattening out and delayed fall. In the case illustrated this was due to a small meningioma lying in front of the cord, which presumably acted like a ball valve

space have been air and iodine containing oils Of these perhaps the best known and most useful is heavy lipiodol a sterile poppy seed oil containing 40 per cent of iodine first used in 1921 by Sicard and Forestier of Paris * Introduced into the cisterna magna by suboccipital puncture (p 392) the blob of this radio-opaque oil in falling through the subarachnoid space is arrested at a site of obstruction The appearance of the arrested blob is sometimes a clue to the nature of the obstruction so that from its shape it is sometimes possible to distinguish extramedullary from intramedullary tumours or to recognize a condition such as meningitis circumscripta serosa (Plate II p 249)

While lipiodol should not be used indiscriminately as a means of diagnosis its use in suspect cases of spinal cord compression is desirable and justifiable It may be employed with advantage also in the majority of cases of spinal tumour even those in which the diagnosis is well-established and the level of the lesion definite because the precise

* Rev Neurol, 1921 28 vi 1264

anatomical relationship between segments of the cord and the bodies and spines of the vertebræ is somewhat variable. Although clinical examination may definitely indicate the site of the tumour at a particular segment, the use of lipiodol so localizes this segment that its exposure may be made with the removal of a minimum number of laminæ.

LAMINECTOMY

Indications.—The operation may be indicated for (1) some cases of spinal injury, (2) certain inflammatory lesions, (3) tumours of the cord or its membranous or bony coverings, (4) spinal hydatid disease, (5) relief of pain by division of posterior nerve-roots or the sensory tracts within the substance of the cord, (6) division of nerve roots other than for pain, e.g., in conditions such as spasmodic torticollis and hyperpiesis, (7) section of extra pyramidal tracts for such conditions as athetosis, (8) cases of herniation or prolapse of intervertebral discs, (9) certain cases of syringomyelia, and (10) certain other conditions such as compression paraplegia produced by Paget's disease (*see p.* 430).

1. Injuries.—Laminectomy is only rarely called for in cases of injury. From time to time surgeons have advocated immediate operation on all cases in which the condition of the patient permits, chiefly with the object of carrying out intra pial decompression. A. R. Allen* showed experimentally that the symptoms produced by severe contusion of the cord may be relieved by incising the dorsal column at the level of the injury, thus allowing the swollen fibres to expand and later to recover. As an emergency operation in man, however, it must be remembered that the mortality is likely to be high and, except in expert hands, further damage to the cord may be produced beyond that of contusion. In the majority of cases of fracture dislocation any damage to the cord is done by a sudden nipping at the time of the accident. The cord may be contused or lacerated and a hæmato myelia may arise at the site of the damage, but these are not lesions for which surgery is indicated. Extra medullary hæmorrhage of sufficient degree to cause compression of the cord is almost unknown,† and provided early and complete reduction of a fracture-dislocation is effected, and maintained by a plaster-of-Paris jacket, the cord is very unlikely to be compressed subsequently. If there be any doubt as to whether there is cord compression, the state of the subarachnoid space should be investigated (*see* p. 894).

Injuries of the cord in civil life are nearly always associated with fracture-dislocations of the vertebræ. The great majority of these lesions are produced by hyperflexion and commonly occur in the lower cervical (e.g., diving into shallow water) and lower thoracic and upper lumbar regions (e.g., falls of mine roof, cargo, etc., on the bent shoulders). From the very first moment, the patient must be guarded

* *Journ. Amer. Med. Assoc.* 1911, lvi, 878.

† Medical Research Council Report on Injuries to the Nervous System, 19[illegible]. Injuries of the Spinal Cord and Cauda Equina.

against further flexion of the spine which may convert an incomplete into a complete lesion, e.g. in the case of the more common thoraco-lumbar lesion he must be carried from the site of the accident fully prone so that the body weight keeps the spine extended. The spinal column must then be immobilized in a position of hyperextension by means of a plaster jacket.

The question of laminectomy in spinal injuries is a difficult one and any decision regarding operation must depend upon a conception of what surgical intervention might be expected to accomplish. Pressure on the cord may be exerted by a missile or in-driven fragment of bone and, while the resulting compression is not progressive and therefore does not demand immediate relief, recovery of a contused cord may be delayed by the presence of the foreign body. Laminectomy in such cases may furthermore prevent late complications such as cicatricial contraction and interference with the cerebro-spinal fluid circulation.

Gunshot injuries.—If seen early, e.g. within eight hours, and if the patient's condition permits, excision of the wound should be carried out at once and the spine immobilized in plaster. If, as sometimes happens, there has been a good deal of loss of substance so that after excision it is not possible to approximate the wound edges, a vaselined gauze pack should be introduced into the excised wound and the spinal column immobilized in a plaster jacket. Dusting the excised wound with powdered sulphanilamide or sulphathiazol appears to be a valuable measure. The case may not, however, be seen until some time has elapsed, and the problem of operation is then complicated by the almost inevitable infection of the tissues. No operation which entails opening the theca is permissible in the presence of a septic wound on account of the danger of causing septic meningitis.

Except in the early case of compound injury when the operation is performed with the object of protecting the patient from infection, laminectomy is better avoided during the period of spinal shock (*see* p. 386), when the functional depression may be sufficient to turn the scale against recovery from what is a severe operation. Furthermore, during the phase of spinal shock it is not possible to estimate the degree of damage to the cord nor to recognize whether the lesion is complete or not, and operations for complete transverse lesions of the cord are futile. Once the cord has been completely divided, recovery of its distal part does not take place. This does not apply to the elements of the cauda equina which, like medullated nerves, should be sutured when divided. Successful suture of the cauda equina must, however, be exceedingly rare. The Official History of the 1914–18 War states: "It is a little remarkable that not a single example has been met with in which the cauda equina has been sutured."

Once spinal shock has passed off it becomes important to know whether the cord lesion is complete or not. This may be apparent from the nature of the injury, which may be such that it is certain the

cord has been divided e g , gross displacement of vertebræ upon one another together with complete absence of any evidence of conduction , but in most cases a decision has to be made from neurological examination alone It should be remembered that a mass flexion reflex with a return of knee jerk and ankle jerk may sometimes be present with a complete transverse lesion of the cord and hence is of no decisive value Spastic paraplegia in extension however, means that the spinal reflex arcs are in communication with intracranial centres by means of the extrapyramidal tracts and therefore that the cord lesion is incomplete similarly *if there is any sensation of light* touch over the skin of the limbs distal to the site of injury of the cord, the spino thalamic tracts are capable of some conduction and the cord lesion is incomplete

If, when the period of spinal shock has terminated, there is evidence that the cord lesion is not complete laminectomy is indicated if (*a*) gross bony deformity is present or a missile is demonstrated radiologically in close proximity to the cord Operation, by removing the source of a local reaction will now assist the restoration of conduction and guard the patient from complications in the form of scar tissue and adhesions, (*b*) an arrest takes place in the recovery of conduction through the damaged cord i e , the patient's progress ceases to be maintained , or (*c*) there is persistent and severe root-pain

In later cases the problem is simpler The onset of any symptoms pointing to late local reaction e g , root-pain or meningitis circumscripta serosa calls for laminectomy

The indications for operation in cases of spinal cord injury may be summarized as follows —

1 Early cases of compound fracture when the patient's condition permits immediate excision of the wound with the object of guarding him from subsequent infection
2 Cases clinically incomplete from the beginning in which progress becomes retarded or arrested
3 Cases which when spinal shock has passed off prove to be incomplete lesions
   (*a*) If the progress is not maintained
   (*b*) If a foreign body or piece of bone is lying in close proximity to the cord
   (*c*) If there is continued sepsis
4 Cases showing the onset of symptoms at a late period

2 Inflammatory lesions —Generally speaking intramedullary inflammatory lesions are not amenable to surgical treatment A few rare cases of abscess in the substance of the cord with recovery of function following laminectomy and evacuation have however, been reported *

* A. J Walton, *Lancet* 1919 i 243 H W Woltman and A W Adson, *Brain* 1926 xlix 193

Inflammatory lesions of the meninges are either acute and diffuse or localized and chronic. In the former no improvement can as a rule be obtained from operative means other than by repeated drainage by spinal punctures. The more chronic forms are either due to syphilis, when the Wassermann and Kahn reactions will be helpful and a course of anti-luetic treatment will be given a trial before operation is undertaken, or else constitute meningitis circumscripta serosa (chronic spinal meningitis of Horsley). The latter condition may clinically simulate spinal tumour but, generally speaking, because of its rather diffuse character, is more difficult to localize to a particular segment or segments. The appearance of the lipiodol blob is characteristic and serves to differentiate the condition when occurring in a localized form from spinal tumour (Plate II, facing p. 249). The findings at operation are characteristic: the arachnoid is matted into strands which have an opaque, rope-like, whitish appearance suggestive of previous inflammation. As a rule some improvement follows the freeing of the cord from these strands, but relapses are common.

Inflammatory changes in the substance of the bone may be due either to osteomyelitis or to tuberculosis, in which case radiology may be helpful in establishing the diagnosis. If osteomyelitis is recognized it should be treated before there is evidence of cord compression. Experience has shown that in the chronic varieties, particularly tuberculous, recovery nearly always follows the application of adequate immobilization and general treatment, and such measures therefore should always receive a trial before operation is considered. Operation however may be required: (1) if there is a progressive increase of symptoms in spite of orthopædic treatment; (2) if there are distressing complications such as severe root pains; or (3) if symptoms appear late and are due to scar tissue.

Intraspinal abscesses have occasionally been met with, the origin of which is obscure.

3. Spinal tumours.*—Tumours may arise from the vertebræ, the meninges, the cord itself, or its nerve roots. Anatomically they may be classified as extra- or intra-thecal and as extra- or intra-medullary; pathologically as either benign or malignant, primary or secondary; while histologically the varieties are many. A review of a large series of cases shows that more than three-fourths of all spinal tumours occur outside the spinal cord, and that these extramedullary tumours are three times more frequently met with inside than outside the theca. Of intrathecal tumours more than two-thirds occupy a dorsal or dorso-lateral position in relation to the cord. Tumours of the cord and meninges occur most frequently in the thoracic region. Intrathecal extramedullary tumours are usually either meningiomas arising in the arachnoid, or neurofibromas arising from nerve roots.†

* Victor Horsley in 1887 was the first to remove a spinal tumour successfully. It was intrathecal and extramedullary, and produced paraplegia from which the patient, an army officer aged 42, made a complete recovery.

† Lambert Rogers, The Surgery of Spinal Tumours, Hunterian Lecture, R.C.S., *Lancet*, 1935, i, 187.

It is important to diagnose, localize and operate on cases of spinal tumour as early as possible. In a few cases this may be done before compression has produced paraplegia, but the majority *do not present* themselves until some degree of paraplegia is established. Obscure cases of spastic paraplegia should always be regarded as suspect cases of spinal tumour and the condition of the subarachnoid space investigated for evidence of encroachment upon it (spinal block). (*See* p. 394.) I have removed tumours from several cases which had been regarded as suffering from disseminated sclerosis.

Spinal tumours exerting pressure on the cord must be differentiated from other causes of cord compression and from degenerative lesions within its substance, because in each case a clinical picture of paraplegia or quadriplegia is produced by interruption of conduction. The condition of the subarachnoid space (p. 394) is all important in differentiating compression from degenerative lesions within the substance of the cord.

Compression paraplegia of rather abrupt onset is frequently due to a metastasis in the spine and careful examination should be made to find the primary tumour. I have met paraplegias of this type in which the primary tumour was in the thyroid gland, the colon, and the testis respectively.

The clinical course of the great majority of spinal tumours is comparatively slow but steadily progressive without remission ("slow but remorseless," Percy Sargent). By contrast, in acute inflammatory conditions such as extradural abscesses, the course is relatively short and associated with pyrexia, while in chronic inflammatory lesions, such as meningitis circumscripta serosa, the course tends to be a variable one with remissions, and the segmental level indicating the site of compression is indefinite and variable. In Pott's disease there may be characteristic X ray appearances and in hydatid disease the blood picture and the cutaneous and serum reactions may establish the diagnosis. In a series of spinal-tumour cases it was found that a feeling of coldness or numbness, especially in one foot, was frequently the initial symptom, but that in others some form of girdle pain occurred at the onset, while in still others weakness (e.g., of the arm or dragging of a leg) was the initial symptom.* The Brown-Séquard type of paralysis which is consequent upon a unilateral cord lesion (i.e., motor paralysis on the side of the lesion and loss of pain, temperature and tactile sensation below the lesion on the opposite side) is only rarely seen and then usually in association with tumours in the cervical region. A partial picture was produced in one of my patients, a man aged 23, who had a large tumour compressing antero-laterally the 1st and 2nd cervical segments on the right side. The rarity of the Brown-Sequard phenomenon probably depends upon the fact that even small lateral displacements of the cord by tumour result in compression not only on the side of the tumour, but also at the diametrically opposite point in the spinal canal, at which the cord is

* A. M. Kennedy and Lambert Rogers, *Lancet* 19[illegible], i, 275; 1930, i, 654.

displaced against the bone By the time the majority of laterally placed tumours manifest their presence hemi-compression has become bilateral compression The greater transverse diameter of the cervical part of the vertebral canal probably accounts for the occasional presence of the syndrome in association with spinal tumours occurring in this region

Schultze of Berlin * Geoffrey Jefferson† and others including myself have noted the comparative painlessness of certain spinal tumours Some form of girdle pain however is often prominent and this root pain has sometimes led to mistakes in diagnosis A patient with a spinal tumour which I removed had previously had appendicectomy performed and an exploration of kidney advised for root pain the nature of which had not been recognized The possibility of root irritation as a cause of pain should always be kept in mind

An even commoner mistake than failure to recognize root pain however is failure to differentiate between spinal tumours and degenerative lesions in the substance of the cord of which the commonest is disseminated sclerosis In five of my series of tumour cases a diagnosis had at one time been made of disseminated sclerosis in two of them by two different consultants ‡ In miners many of whom have nystagmus there is perhaps an even greater tendency to diagnose disseminated sclerosis We should therefore be suspicious of a diagnosis of disseminated sclerosis especially if the clinical course is a steadily progressive one If there is the least doubt it is better to regard the case as a spinal tumour suspect and to investigate the condition of the subarachnoid space for the presence of obstruction If obstruction exists then the case becomes more than suspect and exploration is called for ||

4 Hydatids —In 1897 Sir Victor Horsley reported § a man with symptoms of compression at the level of the region of the 3rd lumbar nerve on opening the spine at the 12th dorsal vertebra we found it was due not to a new growth but to a multiple hydatid cyst of the vertebral column Many cases have been reported since and in areas where hydatids are found such a cause of compression has to be remembered The Casoni reaction may be positive and the blood picture often shows an eosinophilia The cysts are extradural and usually multiple (Fig 224) and may deeply invade the body of one or more vertebræ

5 For the relief of pain by division of posterior nerve roots or the sensory tracts within the substance of the cord —The demoralizing effect of the continued exhibition of analgesic drugs such as morphia has called forth efforts to relieve intractable pain by surgical means At

* *Dtsch med Woch* 191? xxx iii, 676

† *Brit Med Journ.* 19?8 i, 200

‡ *Lancet* 193? i, 187

|| Lambert Rogers, "Laminectomy for Spinal Tumours" *Journ Coll Surg* Australasia, March 1931 iii, 3 3 1

§ *Clin Journ* Jan. 13 1897 p 18?

the level of the spinal cord there are two methods available (i) division of the posterior spinal roots conveying pain impulses into the cord (posterior rhizotomy) and (ii) section in the cord itself of the tracts conducting painful sensory impulses to the brain

(i) *Posterior rhizotomy* —Since it was first suggested in 1888 by Charles Dana as a means of relieving pain the operation has also been performed with the object of abolishing or diminishing spasticity It is frequently known as Foerster s operation after Otfried Foerster of Breslau who developed the technique and brought the operation to the notice of the profession Foerster performed posterior rhizotomy for gastric crisis in the belief that the pain was due to the exalted activity of the reflex arc * and for spasticity resulting from cerebral

Fig 224 —Hydatid cysts may cause cord compression necessitating laminectomy Those shown were a cause of extradural compression paraplegia (4 D) in a man aged 20 and were removed by laminectomy (*Author s case*)

diplegia (Little s disease), since it had been observed that if a patient with disseminated sclerosis developed a posterior column and root lesion e g , tabes, the spasticity due to the sclerosis tended to decrease as the posterior-column disease progressed

For trigeminal neuralgia posterior root section is eminently successful and has the great advantage that since the section is made central to the Gasserian (posterior root) ganglion regeneration does not take place and the relief of pain is therefore permanent Similar relief follows in cases in which pain arises from isolated spinal nerves as in persistent intercostal neuralgia Except for such cases however, and cases of pain due to the posterior roots themselves being involved in some disease process e g strangled by arachnoiditis or damaged by injury, the results of posterior rhizotomy as an analgesic measure are unsatisfactory This is chiefly owing to the wide sensory overlap which necessitates the division of a large series of roots, and to the fact that, owing to interference with reflex activity, such extensive division

* *Surg Gyn Obstet.*, 1913 x 1, 463

cannot be carried out without causing ataxia If the whole of the posterior roots of a limb plexus are severed, the limb becomes practically useless Except, therefore for local root lesions for which posterior rhizotomy is obviously indicated chordotomy is the procedure of choice for the relief of pain The results of posterior root section performed for spasticity have not been encouraging

(ii) *Chordotomy* (A) *Antero lateral tract section*—In 1910 A Schuller of Vienna,* suggested division of the antero-lateral tracts for the gastric crises of tabes and introduced the term chordotomy for the suggested operation The following year W G Spiller, of Philadelphia, carefully observed a patient who had completely lost pain and temperature sensations in the lower limbs and at autopsy was found to have had each Gower s (antero-lateral) tract destroyed by a solitary tubercle Spiller suggested that this tract might be divided for the relief of pain in a case of malignant growth in the cord

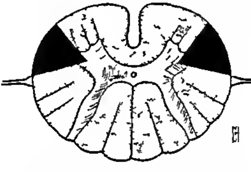


Fig 225—Diagram showing extent of section made in chordotomy for the relief of pain

The operation was performed on January 19, 1911, by Edward Martin who divided both antero lateral tracts to a depth of 2 mm at the level of the 7th dorsal vertebra Pain was alleviated and a year later Spiller regarded the result as successful †

The antero-lateral section of the cord should include a small portion of the anterior column of grey matter, since it is held by some that visceral sensations are carried therein by short chain pathways (Fig 225) The pain fibres cross obliquely *in the cord* and in order, therefore to ensure their complete division the level of the section should be at least four segments above that of the lesion The division is usually carried out at the 4th 5th or 6th thoracic segment, two or three laminæ being removed for the purpose *High cervical operations* have been performed however and I have seen the result of a successful unilateral section for causalgia which was carried out at the level of the 3rd cervical segment ‡ While unilateral chordotomy in the middle or upper cervical region is safe a bilateral operation at this level par

* *Wien med Woch.*, 1910 lx 2292.

† *Journ Amer Med Assoc* 191? lviii, 1489

‡ Lancelot Bromley personal communication 19?7

ticularly when carried out as a one stage procedure, is fraught with the danger of respiratory paralysis

(B) *Posterior longitudinal section* —In 1926 Donald Armour,* acting on the suggestion of Dr G Greenfield, performed a posterior median section of the cord for a patient suffering from severe gastric crisis In this operation advantage is taken of the fact that the pain-fibres cross obliquely over the course of several segments it is the decussation which is divided and the direction of the section is such that no injury to the pyramidal tracts can occur The procedure has been likened to the production of an artificial syringo myelia by division of the median commissure which is destroyed in that disease The section must obviously be carried out just above the level of the lesion A median longitudinal incision about 1 in in length, at the level of the 11th and 12th dorsal and 1st lumbar segments, destroys all pain fibres from the lower limbs and pelvis This operation may be performed on the cervical cord for intractable pain in the arms e g , in a case of intense pain in the arm due to carcinomatous deposits in the axillæ, relief followed it †

Opinions vary as to the exact position of the spinothalmic tract in the cord O R Hyndman and C Van Epps‡ have compared the position of the tract as defined in various text books with their own findings (Fig 226) The spinothalmic fibres from the higher segments are placed anterior to those from more caudal ones By dividing only the anterior portion of the tract therefore, it is possible to abolish pain in the upper part of the trunk without interfering with this sensation in the lower limbs The dentate ligament is attached somewhat posterior to, and not as usually believed, at the coronal axis of the cord As low as the fifth thoracic segment the anterior limit of the tract extends in front of the line of attachment of the anterior nerve roots Hyndman and Epps' findings are the result of their experience of 41 chordotomies 6 of which were performed under local analgesia

Results of chordotomy —Chordotomy may be followed by weakness in the legs, bladder and rectal sphincters, and severe muscle spasm in the legs and back§ and intense girdle pains have also been noted Such untoward symptoms are usually temporary and clear up within the course of a few days or weeks if the section has been properly performed These transient pyramidal effects are probably due to œdema, hæmorrhage or traumatic myelitis The intense girdle pain at the level of the cord section may be avoided by dividing two or three posterior roots at this site G F Stebbing‖ recorded a series of 17 cases on whom he had performed section of the antero lateral tracts , 11 operations were for inoperable cancer and 5 for tabes There were 2 deaths , in the remaining 15 cases the measure of relief

* *Lancet* 1927 i 691

† T J Putnam *Arch Neurol Psych* 1934 xxxi 1193

‡ *Arch Surg* 1939 xxxviii 1036

§ P G Flothow *Surg Clin N Amer* 1933 xiii 1345

‖ *Lancet* 1929 i 654

appeared to justify the operation, and in none was there any permanent ill effect In the tabetic cases, however, the pain tended to return a year or more after the operation H Schloebmann* has recorded his experience of 24 cases of chordotomy The patients were observed for more than one year, most for over three years after operation , 8 were completely relieved, 6 were improved, their pain being much diminished, while 1 case of herpes zoster failed to respond When relapses occur after chordotomy it has been suggested that they may be due to the opening up of auxiliary conducting pathways

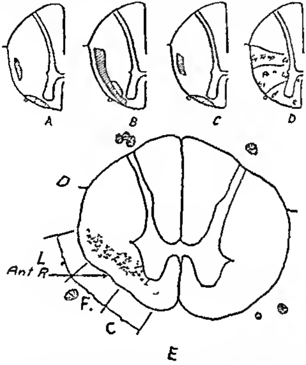


Fig 226 —Diagrammatic representations of the spinothalamic tracts as given by several authors

A drawing taken from Gray (Gray H Anatomy of the Human Body, ed 20 edited by W H Lewis Philadelphia Lea & Febiger 1918 p 759) *B* drawing taken from Tilney and Riley (Tilney F, and Riley H A The Form and Functions of the Central Nervous System New York Paul B Hoeber 1923 p 196) *C* drawing taken from Ranson (Ranson, S W The Anatomy of the Nervous System Philadelphia W B Saunders Company 1920 p 110) *D* drawing taken from Foerster *E* author's concept
L, fibres probably representing the lower extremity *F* fibres representing the groin and abdomen *C* fibres representing the chest *D* dentate ligament *Ant R* line of anterior roots (From *Arch Surg* 1939 xxxviii 1 ...)

(Foerster) I have found chordotomy of distinct value in a few cases of intense pain due to malignant disease

6 Rhizotomy other than for the relief of pain —(i) *Spasmodic torticollis* has been treated by high cervical laminectomy with division of both the anterior and posterior roots of the first three cervical nerves combined with extra-cranial section of the spinal accessory nerve,† but, while results in some cases have been good, others have been disappointing

* *Arch klin Chir.*, 1933 clxxvii 565
† Dandy *Arch. Surg* 1930 xx 1021

(ii) *Hyperpiesis*—Section of the 6th thoracic to the 2nd lumbar anterior nerve-roots has been performed in an attempt to lower blood-pressure and relieve symptoms in malignant hypertension * Recently, however, splanchnic nerve resection, with removal of the cœliac and upper lumbar ganglia, has been found preferable

(iii) *Spasticity* — Posterior rhizotomy to diminish spasticity has proved disappointing and is but rarely practised to day

7. Tract sections performed other than for the relief of pain—In 1924 Spiegel† suggested dividing the extrapyramidal tracts (Fig 227) for the relief of spasticity, and attempts have also been made by Foerster, Tracy Putnam and others to treat paralysis agitans by a similar section By severing the non-pyramidal motor pathways such as the vestibulo spinal, reticulo-spinal and tecto-spinal tracts, which lie in the anterior part of the cord, it was hoped to mitigate symptoms on the same side below the level of the section, but results have not so far been particularly encouraging In 1931 Tracy Putnam‡ performed extrapyramidal tract section for athetosis, and in March, 1940,§ reported 50 operations performed for this condition on 88 patients with 4 post-operative deaths (Fig 228) Most of the patients were pleased with the result of the operation even if it only enabled them to lie quietly in bed or sit up in a chair when this had previously not been possible No patient had been completely relieved but 5 had sufficiently improved to seek employment Machansky|| and others have also claimed favourable results Further reports on extra-pyramidal tract sections are needed before we can reach a conclusion as to their ultimate value and indications

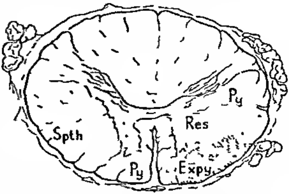


Fig 227—Diagram of the principal pathways in the cervical cord showing the position of the extra-pyramidal tracts (*Expy*) relative to the pyramidal (*Py*) and spino-thalamic (*Spth*) tracts

(After Tracy Putnam *Journ Bone & Joint Surg* 1939 xxi 952)

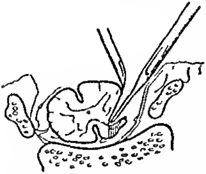


Fig 228—Diagram of the operation of extrapyramidal tract section The cord has been rotated and an incision made at the level of the anterior root attachments

(After Tracy Putnam *Arch Neurol & Psych at Chicago* 1938 xxxix 283)

8 Herniation or prolapse of inter-

* Adson *Proc Staff Meeting Mayo Clinic* 1933 viii 739
† *Jahrb f Psychiat u. Neurol* 1924 xliii 165
‡ *Arch Neurol and Psych.*, 1933 xxix 914
§ *New Eng Surg Journ* 1940 ccii, 473
|| *Sovet Klin* 1936 x 672

vertebral discs —In 1896 Theodor Kocher* reported a case of rupture of the intervertebral disc between the 1st and 2nd lumbar vertebræ in a young man who had succumbed to multiple injuries after falling from a height of 100ft and landing in a standing position There was no fracture of the spine Nodules projecting backwards into the neural canal from the region of the discs have long been recognized and have been variously regarded as myxo chondromas fibromas loose cartilages, fibro-chondromas Schmorl s nodule (Knorpel Knotchen) etc These are now thought to be the result of herniation of the nucleus pulposus of the inter vertebral disc through an annulus in which a fissure has been produced

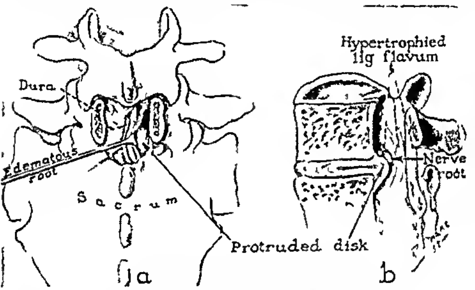


Fig 229 —Protruded intervertebral disc
In (a) a swollen nerve root is shown retracted away from the herniated disc In (b) the protrusion is seen in sagittal section (Reproduced by permission of the Hon Editors, from J Grafton Love Proc Roy Soc Med 1939 xxx 17 8)

by injury or some form of degeneration Injury by a lumbar puncture needle has been regarded as a cause of fissuring (Fig 229) As a result of vascularization subsequently, the herniated nuclear material may undergo calcification or ossification and may be responsible for cord or cauda compression Certain cases of obscure back pain are probably due to these herniations, the pain being produced by stretching of the posterior common ligament † In cases of disc protrusion the cerebro spinal fluid is found to contain a relatively high concentration of protein and by radiography, in appropriate positions after the injection of lipiodol by lumbar puncture the site of the herniated disc may be demonstrated Laminectomy and removal of the herniated part of the disc may afford complete relief There is as yet a good deal of difference of opinion on the frequency with which discs herniate and cause symptoms Dislocations are occasionally found at autopsy and yet have been symptomless during life As a cause of ' sciatica the

* Mitt Grenz geb Med Chir 1896 i, 415 † Mixter and Barr New Eng Journ. Med 1934 ccxi, 210

discs have been indicted to a varying degree Laminectomy has occasionally cured sciatic and low back pain, believed to be due to disc protrusion, and yet no such protrusion was found at the time of operation The explanation may be a recurring dislocation of the disc in certain positions of the spine reduction having taken place at the time of operation

I have recently seen three cases in which removal of a herniated disc has completely relieved sciatic pain but in each instance this has been replaced by low back pain

9 *Syringo-myelia* —Operation for this condition was apparently

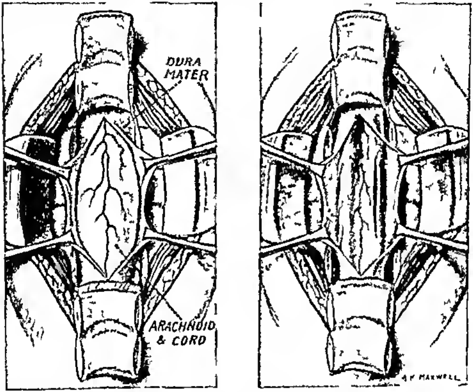


Fig 230 —Laminectomy and incision of cord for syringo-myelia.
(Reproduced by permission from Worster Drought Wakeley and Shafar *Brit Journ Surgery* 1941 xxix 70)

first carried out by Sir Victor Horsley, who, however, never published the case Dr Anthony Feiling has related how Horsley incised the cord and the cerebro-spinal fluid spurted out In 1916 Elsberg opened into a syringo-myelic cavity when exploring for an intramedullary tumour and there was subsequently some amelioration of the patient's condition Following a report by Puusepp* of striking improvement in a patient upon whom he had operated in 1926, Jirasek,† Kelly,‡ C H Frazier and S N Rowe§ and others have given their experiences of operations for syringo myelia The object is to drain the cavities in the cord in the hope of thereby relieving tension and reducing

* *Presse Méd.*, 1932, xl 103.
† Report of 25 cases to Moynihan Chirurgical Club 1933
‡ Report of 10 cases *Trans Med Soc* 1935 lviii 141
§ *Ann. Surg* 1936, civ, 481

œdema but, although there has been some slight improvement in a few patients, the results for the most part have been disappointing. The cause of the cavitation in the cord is not known and the symptoms may well be the result of gliosis or vascular changes rather than of tension within the cavities. Operative treatment is unlikely to retard the progress of the disease or improve cord conduction unless tension and compression are factors and unless, therefore, there is some evidence of encroachment upon the spinal subarachnoid space, as shown by appropriate tests (*see* p 394), surgery has not much to offer in cases of syringo-myelia. If operation is undertaken, a posterior vertical myelotomy in the midline, or a few millimetres lateral to it on the side of the greater cord damage, is the procedure of choice. (Fig 230.) Wound healing in this disease may be retarded and troublesome.

Jefferson* says "The operation has no permanent effect on symptoms and no curative effect on the process itself" (*See* p 480).

The Operation of Laminectomy

Preparation of the patient.—In a clean case, such as a spinal tumour, little special preparation is required. The presence of any *septic focus*

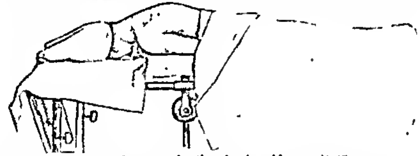


Fig 231 —Position of patient for dorsal laminectomy.

is, however, a grave danger, if the wound becomes infected from a neighbouring bedsore there is a possibility of cerebro-spinal meningitis, while septic infections elsewhere not only depress the powers of resis-

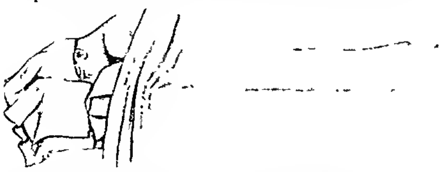


Fig 232 —Position of patient for cervical laminectomy.

tance, and thus add considerably to the risk of an operation of this magnitude, but also increase the postoperative dangers. It is thus most important that the operation be undertaken, if possible, before the onset

* *Lancet*, 1941, ii, 711

of cystitis, bedsores, or bronchitis Should pressure sores be present, every care must be taken to exclude them from the operation field, and thus lessen the possibility of infection, and sulphonamides and hexamine should be administered three times a day for some days both before and after the operation Not only will hexamine improve any cystitis that may be present, but as it passes into the cerebro spinal fluid, it will diminish the risk of the onset of meningitis, since, in the presence of acid forming organisms, it is decomposed into formaldehyde which is inimical to them

In the comparatively rare cases of compound injury calling for late laminectomy, the original wound will generally have healed soundly by the time operation is considered advisable, but if not every effort should be made to diminish sepsis and limit the infection of the wound

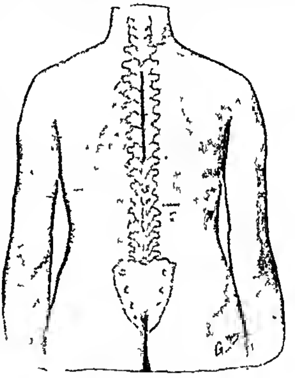


Fig 233 —Skin incision for an upper dorsal laminectomy

Every care must be taken to cleanse surgically the skin of the back The whole area should be carefully shaved so as to remove even the smallest hairs, then washed thoroughly with ether soap and water and gently swabbed with biniodide of mercury and finally *spirit (70 per cent)* Apart from this, little should be done and the administration of strong purgatives on the night before the operation is strongly to be deprecated The patient will have been kept in bed for two or three days previously, and should be given a full diet up to the night before, and taught to become accustomed to lying either fully or three quarters prone, as this is the best position for nursing after the operation On the morning of operation a cup of meat extract should be given some two hours before the anæsthetic is administered

Anæsthetic.—Three quarters of an hour before anæsthetization is begun, the patient is given a hypodermic injection of morphia, grain $\frac{1}{4}$, and atropine, grain $\frac{1}{100}$ Nitrous oxide and oxygen, alone or with ether mixtures, has been found the most satisfactory anæsthetic, but local infiltration with novocain or procain (1 per cent) combined with

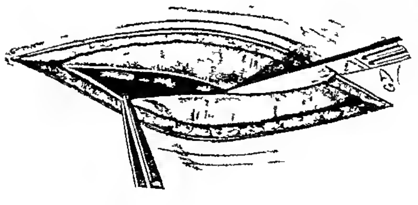


Fig 234 —Laminectomy incision of aponeurosis.

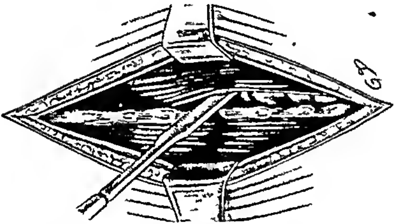


Fig 235 —Laminectomy separation of muscles from laminæ

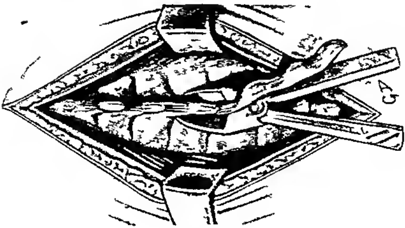


Fig 236 —Laminectomy removal of spinous processes with forceps

adrenaline hydrochloride (5 min to 1 oz) is often sufficient During the operation the anæsthetist should record the pulse rate and systolic blood pressure at five-minute intervals so that any undue drop in blood pressure becomes at once apparent to the surgeon, and a transfusion may be begun or the patient rested until the blood pressure rises again

Technique.—The patient, being sufficiently under the influence of the anæsthetic, is gently rolled into the fully prone position (Figs 231, 232), and sandbags air-cushions or piled up strips of sponge rubber are so placed that the operation field is *supported and the spine made as* convex as possible For the dorsal region little support is required, as this portion of the spine is the most prominent If the lesion is in the lumbar region it is generally necessary to have this portion of the body well supported, so that the lumbar concavity is as far as possible obliterated For lesions in the cervical part of the column the head requires supporting in a slightly flexed position on some form of out rigger, such as is used for cerebellar operations An operation table should be used which is fitted with an extension headrest with shoulder supports to lift the chest clear of the table so that the thoracic respiratory movements are not impaired

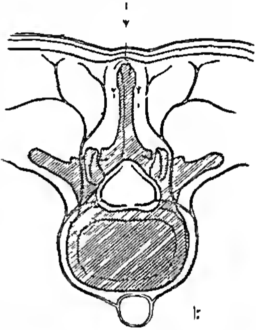


Fig 237—Diagram showing how, by keeping strictly to the midline and close to the bone, it is possible to turn aside the erector spinæ muscle mass out of the vertebral groove without dividing its arterial blood supply

The surgeon stands on the left-hand side of the patient The actual steps of the operation vary considerably in the hands of individual operators, but these variations are, as a rule, only matters of detail which each has mastered in his own way The first essential is to obtain a good view The incision (Fig 233) should be at least 6 to 8 in long, and should have its centre opposite the anticipated site of the disease, in most cases it is possible to determine this very precisely (*see* p 395) The skin of the back has a comparatively poor blood supply when compared with that of the neck or the scalp For this reason, and because it can be readily extended in either direction, if necessary, a straight midline incision is the most satisfactory and is to be preferred to the various "flap" types of exposure The first incision should pass through the subcutaneous tissue, and at this stage a few small subcutaneous vessels require the application of hæmostats

Skin protection cloths should now be attached to the wound-edges and it is advantageous to have these made of thin rubber as a protection to the skin from the frequent hot saline irrigation of the wound. The incision is deepened, the superficial aponeurosis is divided and the deeper muscles are laid bare (Figs 234, 235). An incision is now made through the erector spinæ muscle attachments to one side of the spinous processes and immediately against the bone and with one sweep of the knife this incision is carried directly down to the laminæ. This muscle separation is followed by considerable venous oozing which is controlled by introducing packs of hot moist gauze which are left *in situ* while a similar separation is carried out on the opposite side of the spinous processes. By keeping close to the bone, arterial bleeding is minimized (Fig 237). The wound on this side is now packed with gauze, while the gauze from the first incision is removed to allow the separation of the muscles to be completed. A broad osteotome is the best instrument for this purpose (Fig 238), and it is kept close to the bone so as to effect a subperiosteal separation. When the muscles have been completely separated, the greater part of the hæmorrhage will have ceased as the result of the gauze compression. Oozing is further controlled by self retaining retractors (Fig 239). Some small vessels may have to be ligatured or sealed off with endothermy.

Fig 238 —Author's pattern of broad bladed osteotome for turning the erector spinæ muscle mass out of the vertebral groove subperiosteally

The spinous processes are now isolated and the interspinous ligaments at the limits of the wound are divided with scalpel and scissors. An appropriate number of spinous processes with their intervening ligaments are then removed with bone-cutting forceps (Figs 236 and

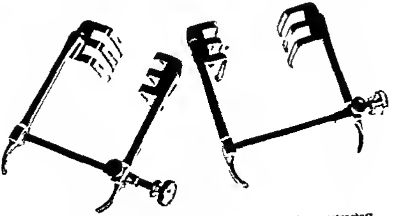


Fig 239 —Author's pattern of self retaining laminectomy retractors.

241) After removal of the spinous processes and ligaments, a clean smooth surface of bone consisting of the posterior aspects of the laminæ, is left exposed in the field

Of the many means adopted to gain an entry into the spinal canal, the simplest and the safest is to trephine one of the laminæ with a ¾-in trephine (Fig 240), from which the pin is removed, or by means of a burr to make an opening between two adjacent lamina To one experienced in the operation *Horsley s* or *Trotter s forceps* alone are usually sufficient to effect this entry The lowest lamina is selected

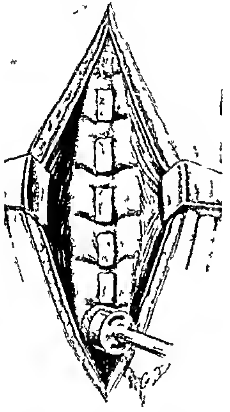


Fig 240—Laminectomy trephining lowest lamina.

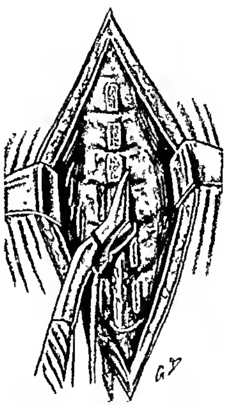


Fig 241—Laminectomy method of dividing laminæ with forceps.

for the site of entry as thereby the opening is made away from the site of the lesion, and the laminæ above are more readily removed by the surgeon working with his right hand It is always advisable to make the opening away from the site of the lesion for, whatever its nature, there is otherwise a possibility that the posterior surface of the dura may be adherent to the deep surface of the laminæ and thus be injured at the time of entry In certain cases of injury an opening may already be found in the lamina, if so it may be easier to enlarge the opening with a pair of small bladed rongeur forceps Some surgeons

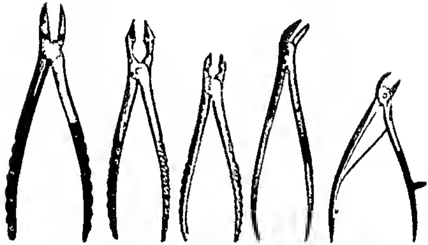


Fig 242 —Forceps used for removing the spinous processes and laminæ

remove all the bone with laminectomy forceps such as those of Horsley others prefer nibbling forceps or a combination of these instrument (Fig 242) Chisels should on no account be used owing to their

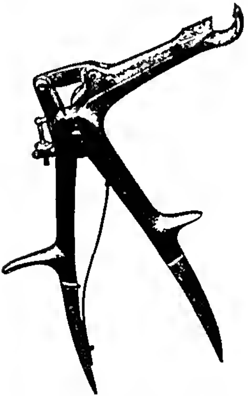


Fig 243a —Guillotine forceps (Hudson s) for widening groove in laminæ

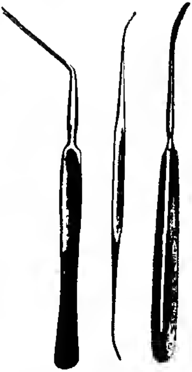


Fig 243b —Instruments for separating dura mater On left is Horsley s dura mater elevato

concussing effect The bone may be dense and very firm, and considerable force required to divide it It must be remembered that this force must at all times be directed outwards away from the dural tube and its contents After an opening is made into the spinal canal, the surface of the underlying dura is cleared of the epidural fat, and the laminæ above are carefully separated by means of Horsley's or other form of dura mater elevator (Fig 243b) One blade of a pair of narrow-bladed cutting forceps is now inserted under the lamina and the bone divided This is repeated on the opposite side, and the lamina removed Great care must be exercised in this procedure

The greater part of the lamina having been removed by the cutting

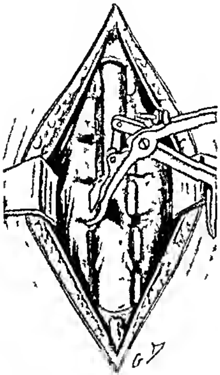


Fig 244 —Laminectomy method of widening groove in laminæ with guillotine forceps

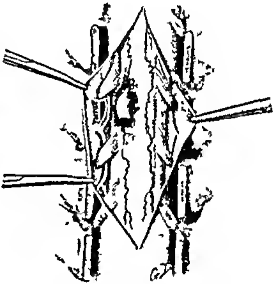


Fig 245 —Foreign body embedded in surface of cord

forceps, the groove in the canal is widened by means of guillotine forceps (Figs 243a 244) These are so made that they cut upwards (i e, outwards) and hence exert no pressure upon the cord The remaining surface of the dura is now carefully cleaned of epidural fat and examined for any adhesions, scarring, or thickening The surrounding surface of bone is also examined for evidence of injury, or for the primary or secondary neoplasm At the same time, any local swelling of the dural tube which may give evidence of a tumour is looked for, and pulsation or its absence noted It not uncommonly happens that pulsation of the dura is present above the lesion but absent below hence, if there be no pulsation in the area of the dura which is laid

bare it is strong evidence that there is some abnormality above the level of the operation field and it may be desirable to remove more laminæ in the upper extremity of the wound Gentle palpation of the dura may yield information and a feeling of localized resistance may reveal the site of an intradural tumour

Unless there is a definitely septic focus outside the dural tube the next step consists in opening the dura As with the bone it is always better to commence the incision in a position remote from what is likely to be the situation of the disease so that if the cord be adherent it is in less danger of injury As the dura is divided sutures of fine silk or catgut threaded on a small curved round bodied needle supported in a needle holder are passed through the edges of the membrane three or four along either side These act as *slings or guys* for retracting the dura as it is opened Care should be taken to incise the dura mater only If this be successfully accomplished the arachnoid will bulge through the length of the incision and any increased tension or any abnormal opacities or thickening as in meningitis serosa will be apparent Frequently it is possible to inspect the cord and its relations through the unopened and transparent arachnoid and the surgeon can sometimes see a beautiful picture of a tumour moving with respiration upwards and downwards in a lake of cerebro-spinal fluid The arachnoid is now opened by snicking it with a small sharp knife cerebro spinal fluid escapes and the membrane is further divided with fine scissors Throughout the operation a stream of hot saline or Ringer's solution should be used This as Horsley showed in his experimental work with the exposed brain of animals lessens operation shock and at the same time keeps the field clear A suction apparatus should be employed to remove the surplus saline and keep the field free from blood The further steps to be taken now depend upon the nature of the lesion

Special considerations *Cases of injury* *—In the more recent lesions the bony canal is carefully examined and if a missile or displaced fragment of bone is present it is removed before the dura is opened At the same time the dura is examined for evidence of injury Unless there is some well defined focus of sepsis externally it should always be opened as by this means alone can the extent of the injury be gauged Small fragments of bone or metal may have penetrated the dura and be entirely overlooked unless it is explored (Fig 245) If there be external sepsis the abscess should be drained and the dura left *unopened* lest a septic meningitis be produced When the dura is opened the surface of the cord should be carefully examined It may be narrowed and flattened showing evidence of pressure Its surface may be roughened inflamed and adherent or it may be completely divided in which case both experimental and clinical evidence have unfortunately shown that there is nothing to be gained from attempts at suturing or from nerve-grafting operations performed upon it In more chronic cases the symptoms may depend upon a

* See footnote on p 395

localized formation of new bone, removal of which is possible In others the symptoms may be caused by displacement or angulation of the bony column, when the mere removal of the laminæ usually relieves the pressure Evidence of scarring of the meninges should be also looked for, and pressure therefrom relieved by simple dissection The consistency of the posterior surface of the cord may be examined by gentle palpation, and knowledge thereby obtained of the presence of intramedullary fibrosis Meningitis circumscripta serosa may be evident, and may be relieved by incising the arachnoid and separating

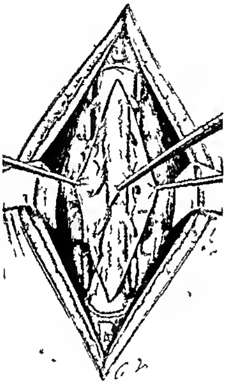


Fig 246 —Rotating cord by a slip of dentate ligament

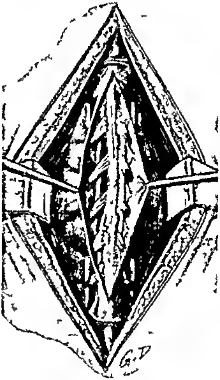


Fig 247 —Meningioma *in situ* (*Sir James Walton's case*)

the adhesions as far as this is possible If nothing be found by these methods, the anterior surface of the cord should be examined To do this without injury, one of the slips of the dentate ligament should be divided at its dural attachment with fine scissors, grasped with forceps, and gently drawn upon so as to rotate or displace the cord (Fig 246) By this means changes in the anterior surface of the cord, or causes of pressure situated on its anterior aspect or that of the membranes become evident

Inflammatory lesions —If an inflammatory change be present in the bone, as in the rare cases of tuberculosis which require operation or which so closely simulate spinal tumour as to have been regarded as

such the lesion should be dealt with before the dura is opened. If after removal of any such inflammatory mass the dura in spite of local thickening be found to pulsate normally, nothing further should be attempted and the wound should be closed. If however, there be persistent local swelling or the normal pulsation be absent, the dura should be opened and any localized collection of fluid or inflammatory material within the meninges evacuated. Should the swelling be in the substance of the cord itself a small vertical incision may be made in the posterior column one or two millimetres from the midline. By this means a localized abscess within the cord may be opened and evacuated.

Neoplastic formations.—If the neoplasm be a secondary deposit and situated in the substance of the bone, the local removal of the laminæ and any mass of tumour which may be pressing on the cord affords temporary relief. A localized osteoma or chondroma growing from the surface of the bone or the dislocated part of an intervertebral disc should be removed. If possible this should be done without opening the dura, but this structure may be so adherent that the lesion can only be satisfactorily dealt with by opening the membrane posteriorly, gently retracting the cord and then incising the anterior aspect of the dura. If nothing is found in the substance of the bone the dura should be opened, when an intrathecal tumour may be revealed.

Fig 248a.—Intrathecal extra medullary meningioma removed from upper thoracic region of a married woman aged 42.

(Author's case.)
(Actual size.)

Fig 248b.—Vacuolated intrathecal extra medullary neurofibroma removed from upper thoracic region of a labourer aged 32.
(Author's case.)
(Actual size.)

In some cases the tumour is seen to cause a bulge in the dural tube or may be felt on palpating it. It is commonly a meningioma arising in the arachnoid (Figs 247 and 248a) or a neuro fibroma growing from a nerve root (Fig 248b). In removing such tumours the same care must be taken as in performing the laminectomy to work at all times away from the cord so that all concussing force is directed away from and never towards the cord. Although no tumour may be actually visible it may be apparent that the cord is displaced or distorted. In such cases its rotation by gently pulling upon a slip of the dentate ligament may bring the tumour into view and allow its removal.

Removal of tumour.—Generally speaking a neuro fibroma growing from the nerve root is easily removed once its arachnoid covering is opened and the root to which it is attached divided. In those meningiomas which are in part adherent to the dura mater it is advisable to remove the involved portion of the dura in addition to the tumour, otherwise meningocytes may be left adherent to the piece of dura and recurrence take place.

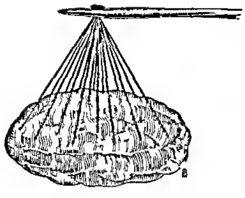


Fig 249 —Removal of a tumour by the multiple thread method

It is sometimes helpful to exert traction on the tumour by multiple sutures of fine silk passed through it particularly in the large tumours occasionally encountered in the cauda equina Such a tumour may be transfixed by a series of fine silk sutures which are then grasped under an equal degree of tension by artery forceps Gentle traction is now made by pulling upon them and the tumour is lifted from its bed (Fig 249) While comparatively little traction breaks a single hair a series of hairs may be pulled upon until the *scalp is avulsed or the individual lifted off the ground* This is the principle applied in this multiple thread traction of tumours

The condition of the cord must always be kept in mind in order to avoid undue retraction or displacement and piecemeal removal of tumours *is sometimes desirable to avoid this It* must again be emphasized that in all manipulations care must be taken to work away from the cord

Blood vessel tumours of the varicose variety which consist of anastomosing dilated pial vessels (varicocele of the spinal cord) if exposed at operation are for the most part better left alone attempts at ligating and separating vessels being ill advised and sometimes disastrous

Intramedullary tumours —Intramedullary tumours differ in type some spinal gliomas growing rapidly being richly supplied with blood vessels and not demarcated from their surroundings while others are circumscribed and of slow growth Tumours of the first variety do not readily lend themselves to surgical removal Some are so soft however that they can be removed without damage to the cord by suction * others of the circumscribed variety may be dissected out and

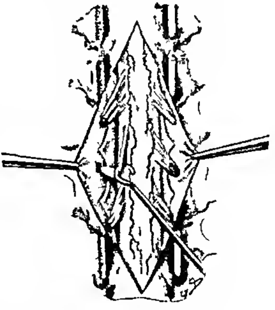


Fig 250 —Posterior rhizotomy elevation of poster or root preparatory to d vision

* H Cushing *Am. Journ. Dis Child* 1927 xxxiii 551

removed completely at a single stage * while less demarcated tumours may be dealt with by the extrusion method of Elsberg

In this procedure a short vertical incision is made through the posterior column close to the midline The tumour may now protrude but no attempt to remove it is made at this stage the wound is closed and re opened a week or ten days later when it is found that the tumour is so far extruded from the substance of the cord as to permit of ready removal without damage to the cord itself

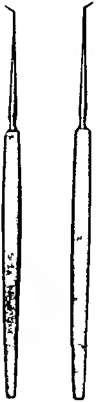


Fig 251 —Chordotomy knives for left and right antero lateral section.

Hydatids —The cysts are extradural and usually multiple and in removing them care must be taken not to rupture them for fear of dissemination The cavities in the bone from which the cysts are removed may be swabbed with formaldehyde to destroy any free scolices but the dural tube should not be swabbed with strong solutions of this substance as a reactionary arachnoiditis of which I have seen an example may ensue

Root section —The roots which it is desired to divide having been identified a blunt hook is passed round them and care taken to separate the nerve bundles from the accompanying vessels (Fig 250) Each root is then divided with a fine sharp knife If there is bleeding from a divided vessel this should be arrested by endothermy by applying a silver clip or by passing a fine silk ligature around it

Chordotomy —The level of section having been decided upon and the appropriate segment exposed by the laminectomy a slip of the dentate ligament is separated from its dural attachment and the cord slightly rotated The appropriate (right or left) chordotomy knife (Fig 251) having been selected the point of the knife is entered immediately in front of the site of attachment of the dentate ligament to the cord and the antero-lateral tract is divided as shown in Fig 252

For posterior longitudinal cord section a small sharp-pointed histoury may be used to make the first incision in the cord (*see* p 403) This is followed by a blunt-ended histoury as the wound deepens so as to avoid injury to the anterior median vessels The type of section which has been made in cases of athetosis is shown in Fig 228 p 405

Prolapsed discs —The herniated portion of the disc may sometimes be easily removed extrathecally by gentle retraction of the dural tube as a whole but in some cases it is preferable to open the dura posteriorly gently rotate and retract the cord (*see* above) and then expose the

* H Cairns *B a s* 1931 liv * 117

protruded cartilage by a second division of the dura anteriorly The fibres of the posterior longitudinal ligament stretched over the projecting nodule are separated from it with a raspatory, and it is removed with nibbling or other suitable forceps assisted by suction (*See also* footnote, p 480)

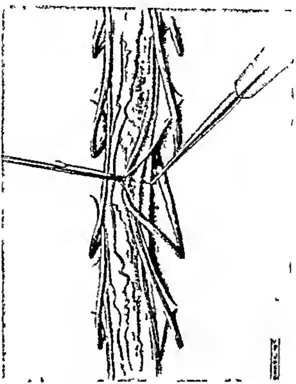


Fig 252 —Chordotomy

Closure of the wound.—Care should be taken to secure a perfectly bloodless field before beginning the closure, and the use of the warm saline stream is particularly valuable at this stage In the majority of cases there is no need to close the dura The muscle masses should be carefully approximated in several layers, using fine silk or catgut passed on a curved round-bodied needle (Fig 253) The closure should be meticulous and accurate and followed by repair of the divided aponeurosis with fine interrupted silk sutures (Fig 254) The skin is closed by *fine, waxed-thread interrupted sutures passed on straight* cutting needles, and a dry dressing is applied and kept in position with strips of elastic adhesive and a many-tailed binder

Hemilaminectomy.—It is usually preferable to perform complete laminectomy, but because of the fear of producing subsequent weakness *of the post-vertebral muscles, hemilaminectomy may be decided upon,* especially if the operation is to be an extensive one in the cervical region The preparation and position of the patient upon the operating table are the same as for complete laminectomy, and a similar incision

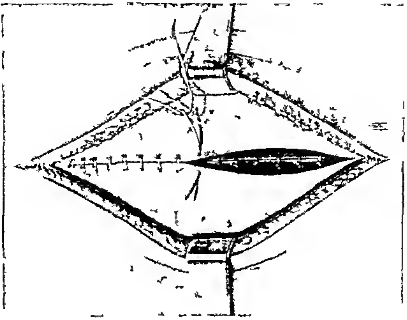


Fig 254 —Laminectomy suture of aponeurosis.

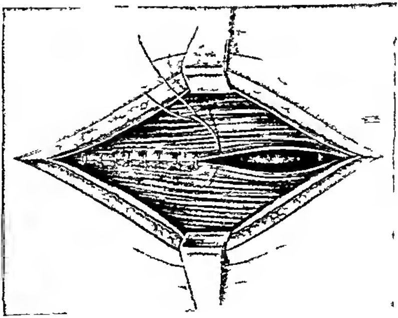


Fig 253 —Laminectomy suture of deep muscles

is made through the skin and superficial aponeurosis The deep muscles are separated from only one side of the neural arches and the laminæ of this side only are removed The spinous processes are retained their bases being sawn or cut through by forceps in an oblique direction so as to leave them attached to the remaining part of the neural arch The dura is divided longitudinally thus exposing the cord and nerve roots The later steps and the after treatment are similar to those of a complete laminectomy

Laminectomy even if extensive is not as a rule followed by any weakness in the spinal column except in the cervical region and then only if the laminæ have been divided very far out or if heavy retraction has interfered with the nerve supply of the post vertebral muscles

After-treatment—According to the patient s condition intravenous saline blood or plasma transfusion may be required either during *the latter part of the operation or on return to the ward* but such measures are not usually necessary Tachycardia may be present after operation and may persist for some hours

Acute postoperative dilatation of the stomach should be watched for and should it arise be treated by passing a stomach tube and washing out the stomach and by changing the position of the patient Failure to recognize this condition may be fatal It is most likely to occur after high cervical operations when it may be the result of interference with descending autonomic impulses in the cord Frequent vomiting of small quantities of dark fluid after a cervical laminectomy should at once raise a suspicion of acute gastric dilatation

The patient is best nursed in the prone or semi prone position and if accustomed to this position for a few days before operation will not find it exacting afterwards Unless there has been any inflammatory condition or there is serious discomfort from the wound it should not be disturbed for ten days

Many patients are completely paralysed at the time of the operation and it not infrequently happens that even if the paralysis is incomplete before operation it may as a result of operative manipulation however carefully carried out be increased for a few days afterwards The after treatment is therefore associated with special nursing difficulties and wherever possible a nurse should be chosen who has had experience of cases of this type

In the care of the patients there are several details which demand attention Because of diminished sensation and trophic changes hot water bottles are best avoided and the patient kept warm by an electric cradle which at the same time keeps the bedclothes away from the lower limbs Great care must be given to the bladder and rectum For several days or weeks regular catheterization may be required and more than usual care must be taken to maintain asepsis especially if there be already a slight cystitis for one of the chief postoperative dangers is the onset of pyelo nephritis Hexamine should be administered regularly as an antiseptic since it is secreted both in the urine and in the cerebro spinal fluid (p 103) If the

retention of urine persist it may be preferable to tie in a catheter and establish tidal drainage (*See also* care of the bladder in para plegic cases p 387) Should it be necessary to give a hypodermic injection this should be administered in some portion of the body above the level of the lesion for even a slight injury may give rise to trophic changes

If the prone position is uncomfortable the patient may be turned to one or other side and the position should be frequently changed to prevent ill-effects from sustained pressure For the first few days after operation the temperature may rise to 102° or 103° F but it generally falls rapidly and must not alone be taken as an indication of the onset of sepsis This immediate postoperative rise of tempera ture probably results from the liberation of cerebro-spinal fluid into the perineural tissues For a time discomfort may be caused by voluntary or involuntary movements of the legs which should therefore be supported by pillows it may even be necessary to administer considerable doses of the bromides Spasticity may increase at this stage and massage should not be instituted until it lessens In certain cases pain and discomfort may be caused by abdominal distension especially if the lesion is above the mid-dorsal region but relief can generally be obtained by the administration of enemas and pituitary extract

Difficulties may very rarely be caused by the escape of cerebro-spinal fluid but this should not occur if the wound has been carefully closed in layers Should cerebro-spinal fluid leak the fistula usually closes spontaneously within the course of a week or two during which time the utmost precautions should be taken to guard against infection and gauze dressings wrung out of spirit (70 per cent) should be used When leakage follows an operation performed within two or three weeks of the infliction of a perforating wound there is considerable risk of sepsis which may later terminate in a meningitis In such cases especially care must be taken with the dressing and sulphon amides and hexamine should be administered Boracic powder is useful as an absorptive which is mildly antiseptic

In every case massage should be instituted when spasticity lessens and should be given at short intervals for a prolonged period By this means not only is nutrition improved but restoration of function is likely to be accelerated

Pressure sores *Prevention* —Every care must be taken to prevent the appearance of these troublesome lesions The effect of pressure-points must be minimized by a water bed air cushions or gauze pads Cleanliness frequent alteration of the patient s position and the avoidance of wet beds are essential The skin must be kept absolutely dry and at least twice daily treated by massaging lightly with methy lated spirit followed by the application of powdered zinc stearate The bed clothes should be kept off the lower limbs by a cradle

Treatment —If bedsores appear deep collections of pus must be evacuated but otherwise sloughs should be allowed to separate and

not cut away, while the position of the patient must be so adjusted as to remove all pressure from the necrosed area

The essentials of after treatment may be summed up as follows —

(a) to watch for acute gastric dilatation or other postoperative complication

(b) to guard against trophic lesions

(c) *to minimize the degree of infection in the urinary tract by* due care of the bladder

(d) to mitigate the discomfort of incontinence and make provision for adequate sleep

Results.—The operation of laminectomy should be associated with but a low mortality, if cases are properly selected, with due consideration to the indications discussed If a careful, bloodless, gentle technique is followed with appropriate after-care, the operative mortality should be less than that for craniotomy, in which complications from previously raised intra meningeal pressure may play a part, but in either case, operative risk depends upon many factors, one of the chief of which will always be the condition for which the operation is performed

OPERATIONS FOR SPINA BIFIDA

Spina bifida is a congenital defect in the bony surroundings of the cord, and is often associated with a protrusion through the defect of the contents of the spinal canal It is usually posterior, involving the laminæ, but may be anterior Anterior spina bifida, which is extremely rare, may be seen as a protrusion of the membranes, or cord and membranes, through the vertebral bodies, which develop in two halves It very rarely occurs in the cervical region, when inspection through the patient's open mouth may show the posterior pharyngeal wall pushed forwards It may also occur in the sacral hollow behind the rectum

The posterior or commoner variety of spina bifida is most often seen in the lumbo sacral region, less often in the cervical, and most rarely in the thoracic region The deformity is estimated to occur once in every 1,000 births (Bland-Sutton), and about 80 per cent of these cases die within the first year of life The sex distribution is practically equal (John Fraser) Motor and sensory disturbances may be present in the lower extremities with loss of control over bladder and rectum

Varieties of spina bifida. (I) Spina bifida occulta —In this variety, which is met with in the lumbo-sacral region, the laminal defect is small and the gap may be occupied by a fibrous-tissue plug to which the cord is adherent (membrana reuniens) There is usually no defect apparent on clinical examination, but a dimple (fossa coccygea), a tuft of hair or a lipoma may mark the site of the defect For a short time after coalescence of the neural folds to form the primitive neural tube, the embryonic cord and superficial epiblast remain in contact Gradually they become separated by a mesodermal

intrusion, which in spina bifida occulta, however, may be defective, in which case the primitive contact between skin structures and cord may persist as the membrana reuniens. During the period of growth, when the development in length of the cord lags behind that of the spinal canal so that at birth the cord terminates at the 3rd lumbar and at puberty at the 1st lumbar vertebra, the lower part of the cord may be under tension from the pull of the fibrous connecting plug and thus give rise to late symptoms. These usually appear between the ages of 8 and 14 and may take the form of incontinence or retention of urine, perforating ulcers on the feet or other trophic disturbances in the lower limbs.* I have operated upon a case in which late symptoms arose following an apparently successful operation for spina bifida early in life. The patient, a girl aged 23 with vascular and trophic lesions (ulcers, necrosis of bone), was relieved by division of a firm fibrous band which anchored the cauda equina to the scar tissue in the skin and passed through the dural tube. The cord terminated at the 3rd lumbar vertebra. Two other patients, under observation, have progressive neurological features at the ages of 4 and 11 years,

Spina bifida occulta is apparent on X-ray examination, and defects in the neural arches are frequently seen in the course of X-ray examinations of patients who possess none of the signs or symptoms of spina bifida occulta. These symptomless cases do not require treatment.

(2) Meningocele.—There is an entire absence of nerve tissue within the sac, which usually has a narrow neck and contains only cerebrospinal fluid.

(3) Meningo-myelocele.—This is the commonest of the gross forms of spina bifida, and the fundus of the sac consists of an area of granulation tissue which is composed of an undifferentiated portion of the cord. Von Recklinghausen described three areas characteristic of the appearances of a meningo-myelocele: (*a*) the area medullo-vasculosa (cord elements) just referred to; (*b*) the zona epithelio-serosa which immediately surrounds it, and (*c*) the zona dermatosa, an incomplete skin covering and the most peripheral area. (Fig. 255.)

(4) Syringo-myelocele.—The protrusion contains the dilated central canal (primitive neural tube) of the spinal cord.

(5) Myelocele or partial rachischisis.—This condition, in which the medullary groove remains in part unclosed, is incompatible with any length of postnatal life and is not amenable to surgical treatment.

Indications for and objects of operation.—The indications for operation in cases of spina bifida are (1) to prevent the onset of meningitis through rupture of the sac and leakage of cerebro-spinal fluid; (2) to remedy the deformity produced by certain types, e.g., meningocele and some cases of meningo-myelocele and syringo-myelocele; (3) to relieve symptoms in spina bifida occulta with neural impairment. Operation is contra-indicated in those cases which show such severe involvement of the cord that the child is

* Sir John Bland Sutton first drew attention to the association of spina bifida occulta with neuro-vascular changes in the lower limbs in a paper, "Spina bifida occulta and its relation to ulcus perforans and pes varus," *Lancet*, 1887, ii, 4.

already or will soon be completely paraplegic, and in cases in which there is an advanced degree of hydrocephalus

Opinions differ as to the best time to operate, but many surgeons, including myself, believe that this is within the first ten days of life The exposed covering of the sac should be free from infection before operation is attempted, but small areas of ulceration are not a contra-indication if they are carefully isolated and not allowed to contaminate the operation field. These ulcerated areas, in which the coverings are very thin, indicate the imminence of cerebro-spinal fluid leakage and the desirability of urgent operation to prevent infection Before

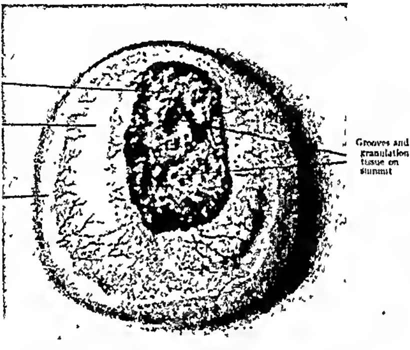


Fig. 255 —Three zones in a myelomeningocele (Bockenheimer)
(Reproduced by permission from Frazier Surgery of the Brain and Spinal Cord, D Appleton & Co, New York, 1918)

operation a spirit or formaldehyde dressing (which is hardening) should be applied to the tumour and the child nursed upon its face, while the tension within the sac may be lowered by puncture and aspiration made through healthy skin at some distance from the thinned summit of the tumour.

Whenever possible, the sac should be preserved. It is believed by many that there is an increased risk of postoperative hydrocephalus when the spina bifida sac has been removed, but in practice it is, unfortunately, not always possible to retain it. It has been suggested that the sac forms an absorbing mechanism comparable with the intracranial arachnoid villi (Penfield and Cole),* and if this is so a

* Journ Amer Med Assoc., 1932, xcviii 454

plastic operation with preservation of the sac is obviously the procedure of choice The particular operation performed must be influenced by the type of spina bifida and the degree of its development but generally speaking the essentials are the dissection of the sac so that it is free from its surroundings and after reducing its fluid content by tapping its infolding or plication so that it occupies the gap in the neural arches In this position it is covered by fascial flaps taken from the dorsal aponeurosis Occasionally the sac is incapable of treatment in this way It must then be opened its redundant portion removed and the gap in the meninges closed with fine silk sutures

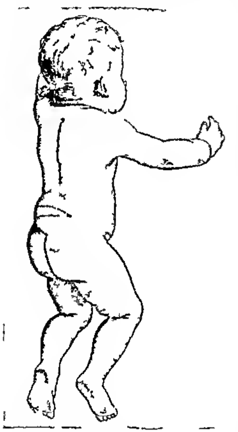


Fig 256 —Diagram of incision for radical cure of spina bifida

Technique —General anæsthesia is best avoided local infiltration of procain (1 per cent) being used or in the very young baby no anæsthetic at all The child is placed upon its face with the head low and precautions are taken to keep the frail little patient warm and to prevent shock The skin incision is either transverse (Fig 256) or longitudinal according to the shape of the sac the nature of its coverings and the position of any areas of ulceration such areas are excised along with the redundant coverings after treatment with pure phenol or the actual cautery The knife used for this purpose is discarded The sac is now isolated by sharp dissection freed from its surroundings and depressed so that it occupies the laminal defect by lying in the gap in the neural arches If this is not possible the sac is opened care being taken not to damage any neural contents which must be freed and replaced in the vertebral canal the distal portion of the sac is excised and a continuous fine silk or thread suture is used to close the part left attached If nerve roots have to be divided care must be taken to ligate the accompanying blood vessels as fatal intrathecal hæmorrhage has occurred from neglect of this precaution (John Fraser) It must be remembered that in the meningo myelocele the area medullo vasculosa is none other than an undifferentiated portion of the cord and must be retained because it contains the

ganglion cells The next step is the further closure of the gap in the vertebral column and although many devices have been employed the simplest and most effective is the formation of overlapping musculo fascial flaps which are sutured by fine silk or thread (Fig 257) The skin flaps which have been fashioned in the first place and retracted during this time are now approximated with fine waxed thread interrupted sutures

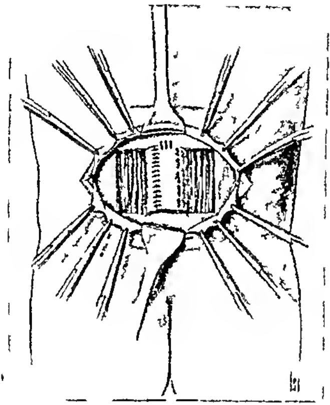


Fig 257 —Overlapping aponeurotic flaps in the repair of spina bifida

Complications and results —The chief complications of operation for spina bifida are infection leading to meningitis which is usually fatal and hydrocephalus which is perhaps more likely to occur if the sac has been resected A later complication is the appearance usually at about puberty or early adolescence of neurological features the result of a drag on the relatively shortened cord by fibrous bands which unite it to the skin and for which operation may be required (p 126) As might be expected the results are best in cases of true meningocele and spina bifida occulta

The treatment of spina bifida occulta which is giving rise to symptoms consists in an exploratory operation which has as its object

the freeing of the cord No treatment is indicated unless symptoms are present and when these appear they usually do so in late childhood or early puberty, so that operation is not indicated until then

Technique —Transverse crescentic incisions are made to include the tuft of hair, the lipoma or the cutaneous depression (fossa coccygea) which indicates the peripheral attachment of the membrana reuniens The fibrous membrane is dissected free from its parietal attachments and followed downwards through the defect in the neural arches Some bone may have to be removed from the margin of the defective arches to give an adequate exposure The band is carefully separated from its neural attachments and the gap in the neural arch is closed in so far as this is possible, by approximating the erector spinæ mass of either side a series of interrupted sutures being used for the purpose The aponeurosis is closed with fine silk interrupted sutures and the skin with interrupted waxed thread stitches, and a dressing applied In the surgery of spina bifida care must be taken to prevent infection, and prophylactic exhibition of sulphonamides and hexamine is advisable

Addendum to page 408

10 Certain other conditions such as paraplegia produced by Paget's disease —J W Aldren Turner has analysed 13 cases of spinal compression due to this disease * Numbness and weakness of the leg advancing to spastic paraplegia accompany the typical bony changes seen in radiography Pain may be troublesome Decompressive laminectomy is of value the bone is soft and bleeds considerably I have operated on one case a man aged 61 who made a gratifying recovery from his paraplegia and now nearly three years later is back at work as a supervising engineer

* *Brain* 1940 lxiii 321

Since this essay was written much work has been done on the intervertebral discs This is well summarised in a recently published book The Intervertebral Disc by D K Bradford and R G Spurling (Thomas, Springfield, Ill., 1941) About 80 per cent of cases of herniated disc occur in men and the maximum incidence is in the fourth decade The site of the protrusion is either between L4 and L5 or L5 and S1 The pain of disc lesions is sciatic in distribution and either persistent or intermittent It is increased by coughing sneezing or straining relieved by resting and made worse on exercise The ankle jerk is diminished or lost in about half of the cases being affected in about 80% of lumbo-sacral herniations and only 25% of 4th lumbar herniations Myelography with air or Lipiodol may decide an indefinite case It is often possible to remove the herniated disc without laminectomy by cutting away the ligamentum subflavum between the laminæ and retracting the dural tube and its contents For further details Bradford and Spurling's monograph should be consulted.

CHAPTER X

OPERATIONS ON NERVES

By HARRY PLATT

I. ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS

Structural anatomy of nerve-trunks.—The conducting elements of a peripheral nerve-trunk are invested by a connective tissue framework which surrounds the entire trunk (the *epineurium*), encloses the individual bundles (the *perineurium*), and is continued into the interior of each bundle to form a delicate sheath around each nerve fibre (the *endoneurium*). The nerve-fibres lie in parallel series, and are packed into bundles like a system of cables. Each fibre contains a slender fibril, which is the outgrowth of a nerve cell situated either in the central nervous system, or in a ganglion of the autonomic nervous system. By this means the nerve cells are brought into anatomical and physiological communication with distant end organs in motor, sensory, or secretory structures. Two distinct types of nerve fibre can be distinguished:—*medullated* and *non medullated*.

The medullated fibre is built up of three constituent elements:—(1) The axis cylinder (or axon), a central conducting fibril; (2) the medullary or myelin sheath, composed of lipoid substances contained in a neurokeratin framework; and (3) the neurilemma or sheath of Schwann which is constricted at regular intervals, forming the nodes of Ranvier. Between each node is a nucleus lying in the myelin and in close contact with the deeper aspect of the neurilemma.

The non-medullated fibre is characterized by the complete absence of myelin sheath.

Internal anatomy of nerve-trunks.—At one time it was held that *the motor bundles supplying the different muscle groups occupied a* constant position in the cross section of a mixed nerve-trunk. It has been shown, however, that the individual nerve-bundles run a spiral course in the long axis of the nerve-trunk so that the topographical arrangement changes repeatedly at different levels. In all the peripheral motor nerves there are intercommunications between bundles and groups of bundles. In the proximal part of a nerve trunk the intraneural plexus provides a coarse grouping of fibres derived from various spinal segments. More distally, finer plexuses are formed which determine the ultimate arrangement of the fibres as they approach their levels of distribution.* In the repair of a clean-cut

* J. L. A. O'Connell, *Journ. Anat.*, July 1936, lxx. 468.

division of a nerve without loss of substance, axial rotation of either the proximal or distal stumps should be avoided. But where there has been destruction of a considerable length of a nerve-trunk, and where extensive freeing of the nerve above and below the site of the injury is necessary, an accurate topographical suture is obviously impracticable.

Degeneration and regeneration of nerve-fibres. Degeneration.—When a nerve-trunk is crushed or divided, the nerve-fibres distal to the point of injury or section undergo a process known as Wallerian degeneration. A similar reaction is seen also in a narrow zone in the proximal trunk in the immediate vicinity of the trauma. The degenerative change is a vital one, and affects all the constituent elements of the fibre.

The axis cylinders become swollen and, after undergoing disintegration, disappear entirely. The myelin sheath breaks up into a collection of globules which are ultimately carried away by the intraneural lymphatics. In the neurilemmal sheath the changes are proliferative; the nuclei stain more deeply, divide, and as a result the old sheaths become filled with new strands of a syncytial-like tissue. These newly-developed neurilemmal fibres were regarded by earlier observers as new axons, but this interpretation is now known to be incorrect.

The process of degeneration involves the whole length of the distal nerve-trunk, and significant changes occur also in the various nerve-endings. Thus, in the motor end-plates the neuro-fibrils become fragmented and finally disappear.

The central ganglionic cells from which the degenerating axons arise also show a reaction to the stimulus of the peripheral injury. The cells become swollen, and exhibit a characteristic staining reaction known as chromatolysis. These retrogressive manifestations are best marked when the nerve injury is severe, and particularly when the lesion is located in the proximal course of the nerve. After a time the cells tend to return to the normal, but under certain circumstances recovery may be entirely absent.

Regeneration.—Degeneration is followed closely by regeneration, so that the two processes are advancing at the same time, the latter close on the heels of the former. All the evidence which is available from experimental, embryological and clinical sources goes to show that the appearance of new nerve-fibres in the degenerated peripheral stump is due solely to the downgrowth of axis cylinders from the central stump.

The earliest regenerative changes are well under way by the end of the first week after nerve section. The axons in the central stump branch profusely, and on their growing ends are seen minute discs or bulbs of varying shape. As the advancing axons reach the distal stump the bundles lose their orderly parallel arrangement, owing to the resistance offered by the healing connective tissue framework. Some fibres turn away from this barrier, others wander outside the limits of the cut surface of the nerve, and may be lost permanently.

The majority of axons however, penetrate the healing zone and enter the neurilemmal channels of the distal stump At this level a regular parallel arrangement reproducing the funicular pattern is once more seen The rate of the downward march of the growing axon has been estimated as one to two millimetres in twenty four hours The new axon ultimately reaches the extreme periphery and grows into an end organ thus the regenerative process achieves its object—the re-establishment of continuity between the central cell and the nerve terminal The new axons do not appear to show a predilection for special channels in the peripheral stump, so that the end organs reached are matters of chance All newly-formed axons are at first non medullated Later the process of myelination begins in the proximal stump and proceeds distally The exact source of the new myelin sheath is unknown The new primitive sheaths are formed from the proliferating neurilemma and in this provision the central and peripheral segments of the nerve take an equal share

The whole regeneration process is initiated and controlled by the central ganglionic cells If the downgrowth of regenerating axons is blocked for a long time, the nerve cells tend to lose their full power of dominating regeneration *Thus is seen the importance of the early surgical repair of a nerve injury*

Operations on peripheral nerve trunks fall into two main classes —

1 **Reconstructive** procedures which aim at the restoration of conductivity in an injured nerve e g *nerve suture, neurolysis, anastomosis, nerve grafting*

2 **Destructive** procedures which involve the deliberate sacrifice of conduction, e g *nerve blocking* (by crushing or injection), *neurotomy neurectomy* The operations in this class are employed either (*a*) for the relief of intractable pain and other irritative symptoms, or (*b*) to eliminate muscular spasm in certain non progressive lesions of the central nervous system

Types of Nerve Injury

Peripheral nerve injuries may be divided into two main groups viz (1) open and (2) closed The term "injury" is used here in a generic sense to include every type of abnormal mechanical influence to which the conducting elements of a nerve trunk may be exposed

1 **"Open" injuries**—In this group the nerve injury is accompanied by an accidental wound

2 **"Closed" injuries**—In the absence of an external wound a nerve trunk may sustain damage in the following circumstances —
(i) *Contusion* or *laceration* due to a single severe blow from without, or to the initial displacement of a bony fragment in an associated fracture
(ii) Continued *compression* or *friction*, the compressing agent may be (*a*) external to the nerve, e g cicatricial tissue, callus, or abnormal skeletal structure (cervical rib), an aneurysmal sac, a new growth, or (*b*) in the substance of the nerve trunk itself, e g interstitial changes

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following hæmorrhage or inflammation and the rare neoplasms of nerve trunks (iii) *Traction* the majority of traction injuries involve the roots or trunks of the brachial plexus and occur either in the infant born after a difficult labour or in adults after falls on the shoulder

II PATHOLOGICAL CONSIDERATIONS

Healing of injured nerves (1) After complete division—When a nerve trunk is divided completely the cut ends retract within a short time On the proximal end a bulb rapidly develops composed

Fig 258 —Transverse section of ulnar nerve in upper arm 1¾ in. above line of suture

Specimen obtained from an amputated limb three years after surgical repair of the nerve A this date there was no sign of restoration of conductivity Intense fibrosis is seen extending around the individual nerve-fibres. (Dark staining areas.) (*Preparation made by D E A Linell*)

of proliferating connective tissue and budding nerve fibres The distal stump may become atrophic and pointed or may acquire a fibrous cap Under such conditions spontaneous regeneration on a large scale is impossible although a few axons may occasionally bridge the gap and reach the distal trunk in which the classical Wallerian degeneration has occurred

Where the nerve-trunk has been severely lacerated with a considerable loss of substance the size of the gap and the connective tissue reaction in and around the area of the lesion constitute insuperable obstacles to regeneration This fibrous tissue reaction is most abundant in a wound contaminated by pyogenic organisms The inimical influence of sepsis has been strikingly illustrated in the

peripheral nerve lesions of modern warfare where a nerve trunk already injured by a missile undergoes further destruction in the early stage of suppuration When the inflammatory reaction has subsided scar tissue formation contributes further to the local obliteration of the nerve trunk Finally the fully matured scar presents an impenetrable barrier which the young axon cannot possibly traverse These are the grosser and purely local effects of wound infection but there is further damage to be reckoned with Toxins or bacteria themselves may travel in the interior of the nerve trunk for a considerable distance above the level of the original lesion An ascending

Fig 259 —Exposure of ulnar nerve in upper two thirds of forearm

The lesion is a complete anatomical division with a moderate gap Note the reversed position of the [illegible] for operations on this nerve

neuritis thus develops the end result of which is a widespread fibrosis in the connective tissue framework of the nerve trunk Such changes have been repeatedly demonstrated in injured nerves many inches above the primary lesion (Fig 258)

(2) **Lesions without loss of continuity**—In the nerve injuries produced by contusion friction or traction with no loss of anatomical continuity the phases of degeneration and attempted regeneration take place inside an intact nerve sheath But here also the amount of connective tissue reaction determines the success or failure of the regenerative efforts When the lesion extends over a considerable length of nerve as in many traction injuries few axis cylinders are able to find a way through the formidable intraneural scar

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The lesion is a complete anatomical division with a moderate gap Note the reversed position of the limb for operations on this nerve

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Changes in other tissues—Changes in structure are also found in the tissues to which the terminal nerve fibres are distributed These changes are due either (*a*) to *disuse*, which is an inevitable sequela of nerve block or (*b*) to *irritation* of sympathetic and sensory axons which remain intact The disuse changes consist in muscular wasting and retarded growth in the skin, hair, and nails The changes dependent on irritation are usually described under the title "trophic" and are characterized by a progressive fibrosis in muscle bellies, tendon sheaths and joint capsules degenerative changes in the superficial tissues and porosis in the bones of the hand or foot

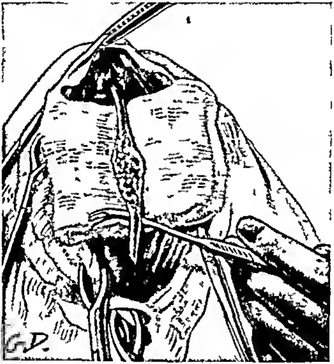

Fig 260 —Exposure of ulnar nerve in upper arm. The lesion is a typical encapsuled nerve-spindle

Types of lesion—The histological changes in a nerve trunk due to injury represent a composite picture to which the primary destruction, the early and late effects of wound sepsis and the attempts at spontaneous repair have all contributed Thus the various lesions commonly disclosed at operation have no exact anatomical or pathological basis But a simple classification is useful to the surgeon, for without a definite schema the correlation of clinical and operative findings is impossible For descriptive purposes it is sufficient to distinguish three main types of lesion (Figs 259, 260, 261) (*a*) Complete division with a gap (*b*) complete division without a gap (pseudo-continuity), (*c*) an intact nerve trunk showing some localized alteration in calibre or consistency In this group the nerve-spindle (fusiform neuroma) is the best-known lesion

III CLINICAL CONSIDERATIONS

It is unnecessary to describe in full detail the symptomatology of nerve injuries but it should be agreed that the surgeon must be competent to undertake the clinical investigation of such patients and that his province is more than that of a mere operator

Clinical syndromes—The state of conductivity in an injured nerve trunk is best considered from the standpoint of the recognition of certain well defined syndromes (1) of complete interruption (2) of incomplete interruption (3) of irritation and (4) of recovery

I **Syndrome of complete interruption**—A complete nerve block may be present at one stage in almost every type of lesion the loss of

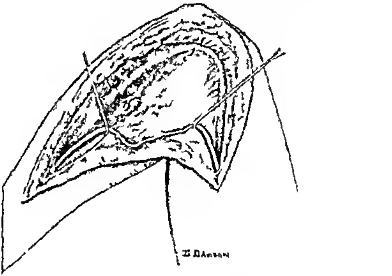

Fig 261—*Exposure of ulnar nerve at elbow and in forearm*
The nerve is seen reduced to an irregular attenuated cord

conduction being either a passing phase or a permanent state (*a*) *Motor signs*—The muscle groups supplied by the injured nerve show a complete paralysis of the lower neuron type—flaccidity wasting loss of deep reflexes and certain alterations in the electrical responses (R D)* (*b*) *Sensory signs*—Sensation is lost in an area representing the exclusive supply of the nerve It is customary to record sensory loss in terms of three types of stimulus—(i) epicritic loss embracing the absence of response to the lightest touch inability to recognize the finer variations in temperature and failure to localize accurately the point of a stimulus (ii) protopathic loss (analgesia) over a less extensive and often ill defined zone where painful stimuli and the extremes of temperature are unrecognized (iii) deep loss characterized by an absence of those afferent impulses from fasciæ muscles tendons

* In the reaction of degeneration (R D) the faradic response is absent the galvanic response is sluggish and shows a polar reversal (A C C > K C C)

and joints which determine the recognition of pressure touch, pressure pain, and their localization The area of deep anæsthesia is usually much smaller than the area of analgesia (c) *Vasomotor, secretory, and trophic signs*—These are inconspicuous in the syndrome of complete block, but the skin may be cold, pale or dusky, and slight retraction of muscles and fibrous changes in the joint capsules may be seen (d) The *injured nerve trunk* is usually painless on direct palpation

II **Syndrome of incomplete interruption**—The syndrome of partial nerve block may represent a fully-matured lesion for an indefinite period Considerable variations may be seen, owing to the presence of conducting nerve-bundles (1) A characteristic picture is often seen in the earlier stages of *compression* or friction lesions consisting of (a) increasing paralysis and muscular atrophy, (b) a dissociated sensory loss with the analgesia (protopathic area) greater than the area of tactile (epicritic) anæsthesia * (2) Another variation is the *distal* syndrome in which the proximal muscles are active but there is a palsy of the distal muscles combined with a more or less complete sensory loss The injured nerve may be thickened and tender

III **Syndrome of irritation (traumatic neuritis)**—This has long been recognized as a striking picture in gunshot injuries, and is also seen in some of the nerve injuries of civil life The signs of partial block are combined with, and often overshadowed by, trophic and sensory phenomena The latter consist of pain, hyperæsthesia, tenderness of the nerve-trunk, cyanosis, glossy skin, brittle and stunted nails and rigid contractures In the most severe form of the irritation syndrome known as *causalgia*, which is seen more especially in gunshot injuries of the median and sciatic nerves, the symptoms are of dramatic intensity Agonizing pain of a bursting or burning type is felt in the hand or foot and is enhanced by all forms of emotional or physical stimuli

IV **Syndrome of recovery**—Tone appears in the wasted muscles, which become unduly sensitive Later there is a return of voluntary power accompanied or preceded by a return of faradic excitability After complete nerve-block sensation reappears in overlapping stages—recovery of deep cutaneous pain, superficial cutaneous pain, coarse touch and finally light touch

Indications for Operation

When a diagnosis of injury to an important nerve-trunk has been made a further problem at once arises It is necessary to decide whether spontaneous recovery is likely to occur, or whether the lesion will demand operative repair In nerve injuries accompanied by an open wound, the damaged nerve may be available for direct inspection during an emergency operation But in subcutaneous injuries the extent of the lesion must usually be assessed on clinical evidence alone

* Stopford, *Brit Med Journ.*, June 19 1926 i 1028

This often means a period of observation lasting from three to six months from the date of the injury If a serious lesion is suspected, it is reasonable to explore the nerve early, and to deal with it in accordance with the findings In a certain number of injuries thus explored for diagnostic purposes the lesion will require no form of repair, but in competent hands no harm will result from the exposure In the graver type of the irritation syndrome early operation is always advisable

IV. OPERATIONS FOR NERVE INJURIES

General Considerations

It is customary to distinguish between the *primary* and *secondary* exploration of an injured nerve

Primary exploration is rarely practised except where the nerve injury is accompanied by an external wound In civil injuries, which are commonly produced by the penetration of sharp instruments, fragments of glass and the like the wound may be comparatively clean ' Under such conditions the immediate suture of a divided nerve is likely to be followed by uninterrupted recovery But where the wound is infected from the outset recovery after primary nerve-suture is problematical, for sepsis is always inimical to regeneration In infected wounds it is often wise to repair less vulnerable structures (e g divided tendons), and to postpone repair of the nerve until a later stage Meanwhile the ends should be approximated by one or two sheath sutures and the nerve-trunk shut off from contact with the infected and injured area When the wound has soundly healed, the nerve should be re explored and repair completed These considerations apply with particular force to gunshot wounds in which gross contamination is the rule

Secondary explorations are undertaken (*a*) after the healing of an accidental wound or (*b*) in "closed ' or subcutaneous nerve injuries produced by contusion compression, or traction In the former a probationary period of from three to six weeks should be allowed after final healing in order to avoid the risk of a recrudescence of infection During this time the nutrition of the injured part should be maintained and improved by appropriate physiotherapeutic treatment Skin-scars should be softened and loosened, and stiffened joints mobilized Such obstacles to free mobility not only add to the difficulty of the exposure of the nerve, but may render the lesion irreparable The operation will be less difficult if attention is also paid to the following preliminary details—(*a*) A wide skin area should be sterilized, which should include the whole limb and often part of the trunk (*b*) suitable splints should be assembled which have already been fitted to the limb in the position likely to be adopted when the operation is completed, (*c*) the correct position of the patient and limb on the operation table should be tried before the sterile sheets are in place Where an alteration in position is necessary in the closing stages of the operation, the arrangements should allow the change to be made with the

minimum disturbance The success of the operation may depend on careful pre-operative rehearsal Many of the operations for extensive nerve injuries are exceedingly difficult and tedious

Exploration of an Injured Nerve

The operation comprises the following steps —

(I) The skin-incision, which is made either over the course of the nerve or in the form of a flap

(II) **Exposure of the nerve-trunk.**—The nerve is usually displaced after opening up a suitable intermuscular space, and is sought for *first above and then below the level of the lesion* The trunk is freed from its bed by gentle dissection, care being taken to avoid injury to the sheath

(III) **Electrical stimulation.**—If the nerve-trunk is intact the response to direct excitation is noted A suitable sterilized electrode (bipolar or unipolar) with long cords connected to a faradic coil, is used *If the unipolar method is adopted, the "pad" electrode should be placed in contact with the patient's body before the operation begins*

In a nerve injury of more than two weeks' standing, a response to the faradic current indicates continuity of nerve-fibres through the lesion A negative response within six months confirms the clinical supposition that actual degeneration of nerve fibres has occurred In a nerve trunk explored many months beyond the normal limits of the spontaneous regeneration period, a lack of response suggests the existence of a *permanent* block to regeneration But a positive response may occasionally be elicited during an operation when the syndrome of complete nerve-block has existed for a long time and pre operative electrical tests have shown an absent faradic reaction in the affected muscles It is believed that regenerated sensory fibres which have grown down motor-sheaths in the distal trunk may acquire connections with motor end organs, and later react to direct faradic stimulation In addition to testing conduction in the injured nerve trunk itself the faradic stimulus is useful in the identification (*a*) of neighbouring nerve trunks in the operation field, and (*b*) of motor branches arising proximal to the lesion

(IV) **Exposure of the lesion.**—At this stage the operation difficulties usually arise owing to the obliteration of landmarks by scar tissue When the area of the lesion is first attacked it is wise to assume that the block of the scar tissue contains intact nerve bundles, however unpromising its appearance A nerve trunk, much distorted and thickened but capable of future conduction, may often be disentangled from a dense scar For this reason all incisions should be made in the long axis of the nerve during the dissection

(V) **Treatment of the lesion**—The method adopted will depend on the extent of the lesion and its effect on the conducting powers of the nerve

(1) **Nerve-block**—Where there is a complete solution of continuity, the operation of *end to-end suture* alone will suffice Where the nerve trunk shows insignificant macroscopical changes as in many of the subcutaneous injuries, freeing of the nerve, removal of the compressing agent, or displacement of the nerve to a new bed is the appropriate measure—i e the operation of *neurolysis*

In many of the graver lesions which show an apparent naked eye continuity, the choice has to be made between *resection* followed by *suture* and the conservative operation of *neurolysis* No hard and fast rules can be laid down The surgeon must attempt to estimate the relative amount of scar and intact nerve-fibres Useful information may sometimes be obtained by incising the nerve-sheath in a longitudinal direction and inspecting the contained bundles When the cicatricial tissue predominates regeneration on a large scale after neurolysis is impossible In long standing nerve injuries presenting such a condition of affairs resection is often indicated, but a cautious attitude should be adopted towards more *recent* injuries, in which neurolysis should be given a trial If recovery does not follow neurolysis the nerve should be re explored without undue delay, and the area of the lesion resected Where the clinical signs point to partial interruption of conduction the choice between resection and neurolysis is often determined by the relative importance of the motor and sensory functions subserved by the injured nerve Thus in the *median nerve* it is reasonable to sacrifice intact *motor* bundles when the obstacles to the regeneration of sensory fibres are admittedly insuperable In the *ulnar nerve* the conditions are reversed, the sensory supply is of little value compared with the function of the intrinsic muscles of the hand

(2) **Irritation syndrome**—So far the nerve lesion has been considered merely in relation to the loss of conduction and the problem of its restoration by operation But in certain nerve injuries the clinical signs are mainly those of *irritation* Many of the milder types of traumatic neuritis respond well to conservative treatment but, if operation becomes advisable neurolysis is the procedure of choice In the special form of the irritation syndrome known as *causalgia*, the affected nerve should always be explored In this condition and in other severe forms of traumatic neuritis conduction must be completely abolished This may be attained in two ways —

(*a*) *Intraneural injection of alcohol*—It has been claimed that 60 per cent alcohol spares the motor fibres and merely produces a temporary block in the sensory bundles of a mixed nerve (Sicard) But if the sensory block is to be truly effective the risk of motor palsy must always be faced In causalgia, complete obliteration is justifiable, for nothing less will relieve the intolerable sensory symptoms The injection technique is simple A fine hypodermic needle is thrust into the nerve trunk above the level of the lesion, and the complete cross section infiltrated with absolute alcohol The nerve becomes distended in the region of the injection and assumes a dead white appearance.

(*b*) *Resection and end to end suture* —Resection of the lesion followed by end to-end suture is a more certain and accurate method of producing complete nerve block and is to be recommended for causalgia

First suggested by Jaboulay *periarterial sympathectomy* has been practised by Leriche* for a wide variety of conditions affecting the extremities in which there is a vaso motor disturbance The operation consists in exposing the main artery in the proximal part of the limb and stripping off the adventitia over a length of about two inches In median causalgia the *axillary* or upper part of the *brachial* artery is denuded in this way in sciatic causalgia the common *femoral* is stripped Modifications of the original technique have been introduced in which the outer coat of the vessel is painted with phenol or infiltrated with alcohol After stripping the artery shows a temporary diminution in calibre succeeded by a dilatation which lasts for a short time only The operation was originally based on the assumption that the sympathetic fibres of the limb join the larger arteries high up and accompany them along the whole of their course This conception is now known to be incorrect for the main sympathetic supply is contained in the peripheral nerve trunks and the fibres are given off to the arteries at successive levels It seems that if sympathectomy is the appropriate operation for the relief of severe traumatic neuritis then the more effective and lasting block secured by *ganglionectomy* is likely to be required Few surgeons other than Leriche have been successful in the treatment of irritative nerve lesions by the periarterial operation

End to end Suture

Difficulties —Where considerable loss of nerve substance has occurred certain technical manoeuvres which facilitate end to-end apposition must be utilized (*a*) The nerve trunk should be exposed and mobilized as widely as possible This can be done with impunity as the intraneural vascular supply alone is sufficient to maintain adequate nutrition † (*b*) The nerve trunk should be fully relaxed by an appropriate change in the position of the limb

Position of Relaxation of Main Nerve trunks

Nerve	Position
Median nerve	*Upper arm close to chest elbow and* wrist fully flexed
Musculo spiral nerve	Upper arm close to chest elbow fully flexed wrist dorsiflexed
Ulnar nerve—if nerve is left behind the internal condyle	Upper arm close to chest elbow extended wrist flexed
Ulnar nerve—if nerve is displaced in front of the epicondyle	Upper arm close to chest elbow and wrist fully flexed
Brachial plexus	Head approximated to shoulder arm elevated or close to chest
Sciatic nerve and its main divisions	Hip hyperextended knee fully flexed

* *Presse Médicale* April [illegible] 1916, xxiv 178.
† Torraca, *Chirurg Deg Organ d Movimento* July 19[illegible] iv [illegible]79

(c) Motor branches arising proximal to the lesion, which always tend to anchor the nerve trunk, should be stripped up from within the nerve-sheath and thus artificially elongated If done with extreme delicacy the small twigs suffer no permanent injury (d) Displacement of the nerve to a new bed in order to shorten its course, e g transposition of the ulnar nerve to the front of the elbow If, in spite of such efforts end to end apposition is still unattainable there re main two alternatives—(e) The two stage operation At the *first* exploration the un trimmed nerve stumps are approximated as closely as possible and anchored by a stout suture, with the limb in the position which affords the maximum relaxation The wound is then closed A few days later gradual stretching of the flexed joint is begun and completed by the end of a fortnight The steady traction tends to elongate the nerve trunk, and so dimi nish the gap In the *second* stage the wound is re opened and an attempt made to com plete the suture (f) Bone shortening This operation has been practised both in the forearm and in the lower limb, but it is generally agreed that it is justifiable only as a method of facilitat-ing repair of the *musculo spiral nerve* when accom-panied by an ununited frac-ture of the *humerus* In such combined injuries, re-freshing and shortening of the bone ends is a necessary step in any operation designed to promote union

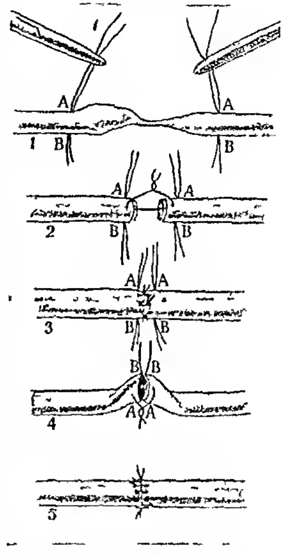

Fig 262 —Technique of nerve suture Shows the various stages in resection and suture *Note* the guide sutures and the approximation of the sheath by interrupted stitches

Suture technique. (Fig 262)—(a) **Trimming the nerve ends** —The essence of nerve suture is to bring normal bundles in the proximal stump into apposition with normal bundles in the distal stump In a

complete anatomical lesion a preliminary trimming of the nerve bulb is necessary where pseudo-continuity is present the injured segment must be resected On the trimmed surfaces there should be no microscopic areas of fibrous tissue Gelatinous bundles in the proximal stump are reasonably safe but when possible it is wiser to resect at a higher level In grave injuries a considerable length of nerve may require resection and the resulting gap may bring the lesion almost into the irreparable class The risk of this dilemma should be ever present in the mind of the surgeon

(*b*) **Coaptation of the surfaces** —When there has been little or no loss of substance the nerve-ends can often be apposed without gross disturbance of the original nerve pattern In extensive injuries this is absolutely impracticable A simple method of ensuring accuracy is to insert guide sutures into the nerve sheath at corresponding points above and below the level of the lesion before resection or trimming is completed The cut surfaces are now brought into bare contact under slight tension crowding or eversion of the bundles should be avoided The actual suture consists in approximating the *nerve sheath* by means of some *half dozen interrupted stitches* It must be remembered that every suture produces a connective tissue reaction along its track but the reaction is minimal when the material is non irritating and of very fine calibre Fine silk or linen thread (160) or *plain* catgut (00000) mounted on slender round bodied atraumatic needles should be prepared for routine use in all operations on peripheral nerves Catgut impregnated with formalin chromic acid or any other chemical is not admissible for this purpose

(*c*) **The nerve bed** —The repaired nerve should be replaced in a bed from which all scar has been removed When possible it should lie in contact with healthy muscle and if necessary should be displaced from its course in order to attain ideal surroundings In certain regions where a suitable bed is unavailable or not easily constructed a sheet of *fascia may be interposed as a covering for such dangerous areas as* denuded bone or tendon The complete investment of the repaired nerve by sleeves of fat fascia or animal membrane is not recommended

NEUROLYSIS

In its limited sense the term *neurolysis* implies the simple release of a nerve trunk from the restraining or constricting effects of scar or other abnormal structures The procedure is thus an essential feature of almost every operation for nerve repair Special technical manœuvres are sometimes included under the heading of neurolysis Thus in dealing with an adherent nerve spindle it is legitimate to dissect off the superficial layers of a densely thickened capsule (capsulectomy neurolysis) Removal of scar tissue from the interior of a nerve-trunk (endoneurolysis) has often been attempted but is mainly a theoretical procedure apt to do more harm than good After the nerve trunk has

been freed and the compressing agent removed, the nerve bed should be reconstructed, or a new bed provided

Operations for Irreparable Nerve Lesions

Irreparable nerve lesions are rare except in gunshot injuries After failure to obtain end to end suture by the two stage operation, the surgeon is faced with the prospect of (*a*) attempting some form of "bridge" operation, or (*b*) abandoning the nerve repair, and later adopting one of the recognized alternative operations on tendons, bones or joints

I **Bridge operations.**—The term is used to describe the various methods of filling in extensive gaps Many operations formerly practised to attain this end are now of purely historical interest, e g bridging by flaps (neuroplasty), fascial tubulization There remain for serious consideration two procedures

(*a*) **Nerve-grafting**—It has been well established in animal experiments that regenerating nerve fibres are able to cross a *short* gap and in their journey utilize the channels afforded by a nerve graft, whether obtained from autogenous homogenous or heterogeneous sources In the earliest grafting operations for nerve injuries it was not realized that a graft unequal in calibre to the lost segment could not possibly convey enough axis cylinders to restore adequate function As an autogenous graft of full calibre was rarely obtainable a method was later tried in which a considerable length of sensory nerve was divided into a number of grafts, and inserted in the gap in "cable" fashion Large nerve grafts (homogenous or heterogeneous) preserved in alcohol have also been used, more particularly by the French surgeons More recently, the implantation of an autogenous graft which has been previously allowed to degenerate *in situ* has been practised The advantages claimed for a degenerated graft are not confirmed in experimental grafting in the cat * In the hands of Duel and Ballance† this technique has been most successful, the results in facial palsy being superior to those obtained from any type of nerve anastomosis A survey of the results of a considerable number of nerve grafting operations has shown that *the majority have been failures, although partial recovery of function* has been recorded in a few cases by competent observers The operation is essentially a last resort and should be practised only where no alternative procedure of equivalent value, such as tendon transplantation, is available

(*b*) **Nerve-crossing** (**nerve anastomosis, lateral implantation**)—Various types of nerve-crossing have been tested both in experimental work and in the repair of nerve injuries In the earlier operations the distal end of the injured nerve was either implanted into a slit in a neighbouring sound nerve or, more exceptionally sutured to its central end after complete section Later the method of *double* lateral implantation

* *Bentley and Hill Brit Journ Surg* 1936, xxiv 94
† *Surg Gyn Obst.*, Feb 1933 lvi 38

was introduced * In this procedure both the central and distal ends of the injured nerve are implanted some little distance apart into the receiving nerve which provides as it were a living bridge

Under experimental conditions the feasibility of restoring function by nerve-crossing has been repeatedly proved but when this operation is applied to the treatment of nerve injuries in the human subject it is attended by obvious disadvantages In the first place the reinforcing nerve must be deliberately injured although such a sacrifice may conceivably be justifiable It has been claimed however that the disturbance of conduction is negligible when double implantation is carried out with great delicacy Then again as in other types of bridge operation a limited number of axons will gain admission to the empty sheaths of the distal trunk and of these few if any will reach suitable end organs But when due allowance has been made for such imperfections the operation of nerve-crossing has achieved some degree of success as a method of indirect nerve repair in certain situations Its scope may be briefly considered in relation to (i) the facial nerve (ii) the brachial plexus and (iii) the larger nerves of the upper limb

Facial nerve—The first nerve-crossing for facial palsy was done in 1895 (Drobnik) the *spinal accessory* being chosen as the reinforcing nerve The operation was practised with occasional success for many years but later was supplanted by *facio hypoglossal* anastomosis which involved the lesser sacrifice of the relatively unimportant lingual muscles *Facio-glossopharyngeal* anastomosis by the end to-end method has also been tried and is regarded by some authorities as a definite advance in technique † Nerve anastomosis in facial palsy however seems likely to pass into the category of operations of historical interest *See* Operations on the Facial Nerve (p 471)

Brachial plexus—Experimental nerve-crossing after the division of two or more brachial plexus roots in monkeys has been followed by genuine restoration of function (Kennedy) In the small proportion of complicated plexus injuries where end to-end suture is feasible after resection of the block the distal trunks often outnumber the proximal trunks In such circumstances the operation of repair becomes in part at least an unavoidable experiment in nerve crossing

Upper limb nerve trunks—There are many examples on record where incomplete peripheral anastomosis between the *median* and *ulnar* nerves has resulted in permanent damage to the recipient nerve with no compensatory restoration of function in the injured nerve The operation therefore cannot be recommended A few examples of partial motor and sensory recovery following double lateral implantation have been observed (Joyce) At the present time however all forms of nerve crossing in the upper limb are *sub judice* and are best avoided

II Alternative operations—The operations which fall under this heading are designed either (1) to restore lost motor function or (2) to eliminate a painful useless or dangerous limb The available recon

* Ballance *Brit. Journ. Surg* 1923 xiii, 51
† Ballance *Brit Med Journ* Aug 3 1924 ii, 349

structive procedures have long been practised in the residual paralyses of anterior poliomyelitis In irreparable nerve injuries the following operations may be used with advantage —

(*a*) Tendon transplantation —In lesions of the *musculo spiral* (and posterior interosseous) transplantation of the pronator radii teres into the radial extensors the flexor carpi radialis into the short thumb extensors and the flexor carpi ulnaris into the long thumb extensors and extensors of the fingers gives striking results In *median* lesions opposition of the thumb may be restored by an appropriate tendon transplantation (*see* p 167)

(*b*) Arthrodesis to stabilize a flail joint accompanying an extensive palsy The operation is chiefly practised on the shoulder joint and smaller joints of the foot (*see* p 122)

(*c*) Amputation is chiefly called for in old sciatic injuries with pain and intractable ulceration of the foot (*see* p 177)

V OPERATIONS ON INDIVIDUAL NERVE-TRUNKS

Operations on the Brachial Plexus

Indications —The more important lesions for which operative exploration may be required are (*a*) Traction injuries of the supra clavicular trunks (birth palsy traction lesions of the adult) (*b*) compression or friction neuritis of the *lower* trunks associated with a cervical rib (*c*) penetrating injuries accidental or gunshot wounds involving the supraclavicular or infraclavicular regions where the great vessels have escaped immediate serious damage (*d*) contusion of the infra clavicular trunks complicating shoulder joint dislocations and injuries of the upper end of the humerus or glenoid fossa

Special anatomical features —(1) The supraclavicular nerve trunks are invested by a fascial sheath which is peculiarly dense under normal conditions and which when invaded by scar tissue makes the dis entanglement of the nerves an exceedingly difficult feat

(2) The two scalene muscles are the main guides to the upper part of the plexus

(3) Certain of the smaller primary branches of the cervical or brachial plexus are important anatomical landmarks These are the nerve to the rhomboids the nerve of Bell and the phrenic nerve

(4) The suprascapular nerve which is comparatively large and easily exposed when traced upwards enables the surgeon to display the junction of the 5th and 6th cervical anterior primary divisions

(5) To expose effectively the lowest trunk of the brachial plexus the subclavian artery must be freed by delicate dissection and gently retracted In this region the relation of the structures to the first rib and to the dome of the pleura must be recalled

(6) In the more extensive lesions in which end to end suture of several trunks is necessary, division of the clavicle is an essential step

Preparations for operation.—(1) In the graver traction or penetrating lesions where end-to-end suture is likely to be required, *postoperative relaxation* of the sutured nerve-trunks must be provided for. This will mean approximation of the head to the shoulder, with the arm abducted or even fully elevated. A moulded splint or plaster-of-Paris shell should be constructed in advance. (2) The skin preparation should include the whole neck (the lower occipital region should be shaved), half the upper

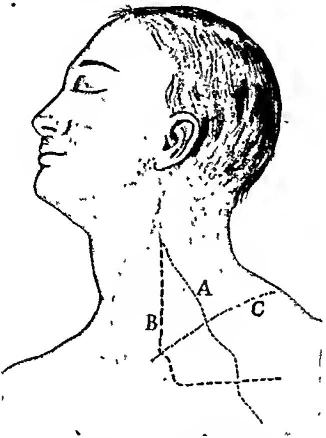

Fig 263—Exploration of brachial plexus Shows three types of skin incision.

chest, and the upper limb as far as the finger-tips (3) As it may be necessary to divide the clavicle, drills, saws and bone-suture material should be included in the armamentarium

Position on the operating-table.—The patient is placed on his back, with a small sandbag between the shoulder-blades The arm on the operation side is pulled down close to the body, and the head tilted towards the opposite shoulder. The anæsthetist should use one of the recognized "long distance" methods of administration which allows the head of the patient to be covered completely by sterile towels.

Skin-incision.—The choice is offered of —

(*a*) A *flap* with a vertical limb skirting the posterior border of the sterno-mastoid in the lower half, and a horizontal limb placed in the infraclavicular hollow (Stiles) (Fig 263, B) For exposure of the infraclavicular plexus an additional incision is carried downwards over the anterior fold of the axilla

(*b*) A *single* oblique cut, beginning at the posterior border of the sterno-mastoid and ending below over the coracoid (Fig 263, A)

(*c*) A *transverse* incision across the root of the neck at right angles to the line of the plexus trunks (A S Taylor) (Fig 263, C) This gives admirable access

Exposure of the supraclavicular trunks and branches.—The various stages may be described in sequence —

I The skin-flap is reflected and the platysma divided along the same line The lateral border of the sterno mastoid is defined and the deep fascia divided above the clavicle This outlines the supraclavicular pad of fat and lymphatic glands which should be carefully turned aside and preserved The external jugular vein will now require ligature and the omo-hyoid muscle, which also bars the way to the nerve-trunks, should be divided With adequate retraction of the sterno-mastoid the anterior and middle scalene muscles are clearly displayed, and between them the *upper* and *middle* trunks of the plexus appear enclosed in a common fascial sheath The latter is often peculiarly tough and is closely fixed to the sheath of the scalenus medius

II *The upper trunk* is short and divides at Erb's point into three branches (*a*) the suprascapular nerve, (*b*) the branch to the outer cord, and (*c*) a branch to the posterior cord The first-named, when traced upwards, is a useful guide to the main trunk If necessary, the anterior primary divisions of the 5th and 6th cervical nerves may be followed up to the level of the cervical transverse processes

The middle trunk is intimately related to the upper trunk in the common sheath In the presence of scar tissue, the disentanglement of the nerve-trunks from the scalenes is often a most difficult and tedious affair

At this stage in the supraclavicular dissection there are certain smaller branches whose recognition and conservation is important The *phrenic* nerve lies on the anterior surface of the scalenus anticus and is easily seen when the sterno-mastoid is retracted mesially The *long thoracic* nerve (nerve of Bell) should be found piercing the scalenus medius in the upper part of the wound, with the nerve to the rhomboids at a still higher level Where there is little scar tissue the slender nerve to the *subclavius* is often demonstrable

III *The lowest trunk* which lies on the first rib next comes into the field, but is somewhat hidden until the suprascapular and transverse

cervical veins have been divided and tied and the subclavian artery has been gently mobilized and retracted downwards The parent roots of the trunk (8th cervical and 1st dorsal) may be fully exposed by detaching the whole or part of the scalenus anticus muscle from the rib The thin fascial covering over the pleural dome and the pleura itself are easily torn an accident of little significance but one which should be avoided if possible

Removal of a cervical rib—As the exposure of the lowest trunk is the anatomical basis of the removal of a cervical rib the special features of this operation are conveniently described here

Supernumerary ribs vary in size and type (1) The common and primitive type is an exaggeration of the costal process of the 7th cervical vertebra from the tip of which a fibrous band runs downwards to be attacbed below to the first dorsal rib (2) In marked contrast is the fully developed cervical rib articulated to the vertebra and fused at its anterior end to the first rib

The relation of the plexus trunks to the extra rib is also variable A common arrangement is for the 7th cervical (or middle trunk) to cross its bony part whilst the 8th cervical (or lowest trunk) passes over the fibrous prolongation The subclavian artery which lies in front of the rib may show a slight dilatation and its pulsation may be unusually well marked The suprascapular or transversalis colli vessels often run transversely in close contact with the rib The subclavian vein at a lower level is out of the operation field In the rudimentary type the costal process lies hidden in tbe fibres of the middle scalene and is most readily approached between tbe upper and middle trunks adequate retraction in this interval also allows the fibrous band to be clearly displayed After the rib has been clearly defined and the neurovascular structures related to it freed it is divided above at the level of the transverse process and below at its junction with the first dorsal rib When all muscular and fascial attachments have been divided tbe rib can be neatly lifted out of the wound If a periosteal sheatb is left behind re-formation of the rib may occur

Removal of the 1st dorsal rib—Removal of a normal or rudimentary 1st dorsal rib has been practised with considerable success in certain cases of compression neuritis of the lower trunk where no definite cervical rib has been demonstrable It is probable however that the neuritis in these cases is due to the presence of the fibrous band contained in the scalenus medius which represents the 7th cervical rib in its most rudimentary stage

As removal of this band or division of the muscle alone is sufficient to free the lower trunk it should rarely be necessary to resect the portion of rib to which both the band and the middle scalene are inserted If for any reason removal of part of the rib is considered desirable the plexus trunks sbould be freed and retracted as described The middle scalene attachment is then separated from the upper surface of the rib the intercostals and serratus from the outer border

and lastly the pleural fascia from its inner border Carefully protecting the pleura the bared portion of the rib is divided in front and behind and removed

A considerable dead space is left which should be obliterated by the deeper sutures

Exposure of the complete plexus (Fig 264)—This is required in the grave lesions involving multiple trunks when end to-end suture is necessary The supraclavicular exposure is the first stage the infraclavicular exposure is effected in the following manner The additional skin incision will be required

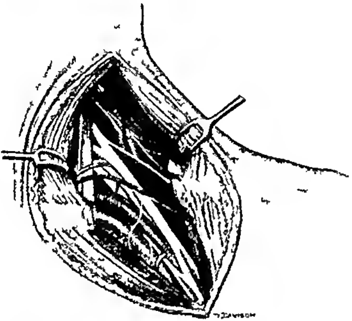

Fig 264 —Complete exposure of brachial plexus after division of clavicle

1 **Division of the clavicle** —The clavicle is bared subperiosteally in its middle third and drilled on each side of the proposed line of section * The drill holes should be so placed that the suture knot will lie buried under the lower border of the bone when the ends are approximated The section is conveniently begun by means of a Gigli saw and completed by bone cutting forceps The shoulder now drops backwards and downwards and a gap is opened up

2 **Exposure of the infraclavicular nerve trunks** When the ends of the clavicle are retracted the nerve-trunks are still hidden by the subclavius muscle and costo coracoid membrane This musculo aponeurotic barrier must be cautiously divided and the dissection continued lower down in the interval between the deltoid and pectoralis

major fibres The external anterior thoracic nerve is often seen at this juncture and as the apex of the axilla is opened up the three *secondary* trunks (cords) are identified in close relation to the axillary vessels their sheaths being most intimately connected The *outer* and *posterior* cords lie above and lateral to the vessels The *inner* cord is just on the point of crossing behind the artery

Repair of plexus lesions. **Supraclavicular** injuries—(1) In the graver traction lesions both in the child (birth palsy) and adults formidable difficulties are encountered in the actual exposure and identification of the nerve trunks and in their subsequent repair In

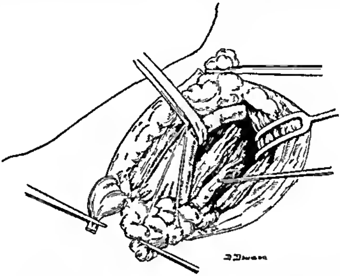

Fig 265—Severe lesion of the supraclavicular brachial plexus trunks The outer trunk is intact the middle and inner trunks have been avulsed high up close to the intervertebral foramina

multiple trunk injuries the lesions are invariably concentrated at different levels with the result that the supraclavicular nerves later become incorporated in a dense mass of scar which also contains the fibrous remains of the scalene muscles But in the midst of such an extensive cicatrix nerve bundles often remain intact and further recovery of function may be anticipated The 5th and 6th nerves are usually recognizable just below the cervical transverse processes but almost immediately plunge into the block of scar The 7th nerve joins a little lower down A not uncommon condition is to find the middle trunk completely avulsed at the level of the intervertebral foramen (Fig 265) The lower trunk is generally intact although much indurated Just above the clavicle the distal trunks are seen to emerge from the lower pole of the cicatricial mass In this complex scar Erb s point and the various divisions and fusions of the primary trunks which form the secondary plexus trunks lie hidden In my experience it is often possible by patient dissection to disentangle nerve trunks which show naked eye pseudo-continuity The choice between a

neurolysis and the radical operation of *resection and suture* must then be made. If there are very few intact bundles a neurolysis will in no way further the regenerative process. On the other hand, in a removal *en masse* of the intervening block of scar, conducting bundles are almost certain to be sacrificed and a considerable gap remains to be closed, with the distal nerve stumps outnumbering the proximal stumps. Experience has shown that it is wise to adopt a conservative attitude towards multiple trunk lesions when, after resection, end-to-end suture may prove difficult or impracticable. When the main nerve-trunks have been isolated the fibrous remains of the scalenus anticus should always be removed, care being taken to preserve the phrenic nerve. This step allows the nerve-trunks to be mobilized to the utmost and in my opinion is essential in a neurolysis of the plexus.

In the rare lesions treated by resection, when suture is performed under considerable tension, the most complete relaxation of the brachial trunks is required, with the head and shoulder approximated and the upper arm in full elevation.

(2) *Circumscribed lesions* of the plexus are more easily dealt with. Of these the traction injury concentrated at Erb's point is perhaps the most familiar type. When resection is performed at this level, the operation consists of suture of *two* proximal trunks (5th and 6th) to *three* distal trunks (suprascapular nerve, branch to the outer cord, branch to the posterior cord). In spite of discrepancies in calibre it is generally possible to effect an accurate and artistic repair.

Infraclavicular injuries, when due to wounds, may be complicated by involvement of the great vessels. In non fatal cases the axillary artery has usually been ligatured as a life-saving measure, the nerve injury presenting itself for treatment at a later date. Where the arterial lesion is incomplete at the onset an aneurysm may develop. The nerve-trunks are generally found closely adherent to the aneurysmal sac, or to the remains of the artery. After freeing the nerves, the fibrous cord of the thrombosed vessel should be removed entirely.

Closure of the wound.—Where, after complete removal of the scar tissue surrounding the supraclavicular trunks, it has been impossible to conserve the supraclavicular fat-pad, little more than the skin-flap may remain to cover the repaired nerves. Under such circumstances it is wise to introduce a connective tissue covering for the supraclavicular triangle. For this a sheet of fascia lata affixed by a few sutures at the edges is most satisfactory. Whenever possible the platysma should be restored by accurate suturing. The clavicle ends are best apposed and fixed by double silkworm gut sutures with the knots well buried. The skin incision should be closed with a view to ensuring a creditable cosmetic result.

Postoperative position.—The position of fullest relaxation of the repaired trunks should be maintained for a week. At the end of this time the head may be released, but the arm should not be lowered until a fortnight has elapsed. Relaxation of the paralysed muscles will be

continued until signs of recovery appear In the earlier stages of after-treatment a special effort should be made to prevent matting of the tissues in the supraclavicular region

Exploration of the Plexus Cords and Chief Branches in the Axilla

Position of patient.—The upper limb is placed at right angles to the operating-table, resting on a narrow support

Skin incision.—Beginning below the clavicle, the incision runs downwards over the anterior axillary fold and is continued in the upper arm along the line of the coraco brachialis muscle

Exposure of the nerve-trunks.—The pectoralis major fibres are divided freely, and the nerve trunks first approached in the lower part of the wound and next at the apex of the axilla With the proximal and distal exposure completed, it is simple to work downwards and display the trunks in their middle course In the *distal* part of the field the inner edge of the coraco brachialis is defined as the main guide to the median nerve which overlaps the axillary artery on the lateral side The *ulnar* nerve is mesial to the vessel, but in a more posterior plane At the *proximal* limits of the wound, the pectoralis minor muscle is found to screen off a considerable area, and is therefore best divided Immediately below the clavicle the three secondary plexus trunks are identified in relation to the vessels At a lower level the main upper limb nerves are displayed in turn (*a*) On the outer wall of the axilla, at the level of the coracoid, the *musculo-cutaneous* nerve is seen to enter the *coraco-brachialis* (*b*) The outer head of the *median* nerve leads to the main trunk, which runs lateral to the axillary artery The proximal part of the median nerve is surrounded by the venæ comites of the axillary artery, and its separation must be carried out with caution (*c*) The *ulnar* nerve is in close relation to the axillary vein Near by are the less important sensory nerves—the internal cutaneous and lesser internal cutaneous—which are likely to escape recognition where dense scar is present (*d*) The *musculo-spiral* nerve is hidden from view, as it lies on the posterior axillary wall In the upper part of its axillary course it is approached by retracting the larger vessels and nerve-trunks outwards Lower down the interval between artery and vein is the natural plane, the former is retracted with the median and musculo-spiral nerve, and the latter with the ulnar (Stiles) The upper branches supplying the *triceps* muscle appear at the level of the *latissimus dorsi* tendon, and should be carefully protected (*e*) The smaller branches of the posterior cord —the *circumflex* and *subscapular* nerves—can be exposed if necessary at this stage In actual practice exploration of the plexus in the axilla is usually undertaken in the presence of extensive scarring and when the axillary artery is a mere fibrous cord The disentanglement and identification of the nerve-trunks, often a formidable task, is rendered especially difficult by the venous hæmorrhage which so often occurs

Where suture of one or more of the large trunks is required the arm must be brought close to the body a position which renders closure of the wound awkward In the majority of operations ample relaxa tion is afforded by bringing the upper arm vertical to the plane of the operating table In this position the operator can work with little or no inconvenience

Operations on the Musculo spiral Nerve

Indications —The lesions demanding operation may be (1) *Pene trating wounds* which are particularly common in modern warfare

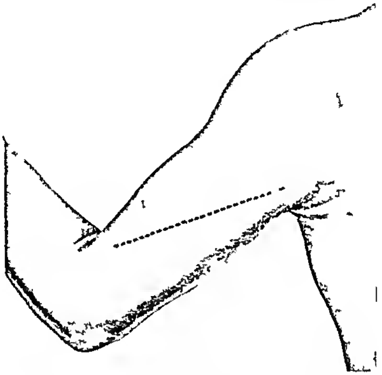

Fig 266 —Exposure of the musculo sp ral nerve Sk n inc s on

Gunshot injuries are usually combined with comminuted fractures of the humerus which show a predilection for non union Operative attack is almost invariably required on both the nerve injury and fracture but the two procedures should *not* be carried out at the same sitting In order to avoid the risk of a recrudescence of infection and the disturbance of the repaired nerve fixation of the fracture should be obtained before the nerve-suture is attempted

(2) *Subcutaneous injuries* not infrequently complicate fractures of the shaft of the humerus or supracondylar fractures Although spontaneous recovery is often seen the nerve trunk is occasionally severely damaged as it passes over a sharp projecting fragment and in such circumstances operative repair becomes imperative

Special anatomical features.—(1) The branches to the constituent heads of the triceps muscle, four in number, arise above the level of most injuries of this nerve. The uppermost branch (to the long head) is usually seen when the nerve is exposed in the lower part of the axilla as it crosses the latissimus dorsi. The lowest of the four (to the inner head) arises just as the nerve trunk enters the musculo-spiral groove. All four branches are capable of being stripped from within the nerve-sheath high up into the axilla, where they originate from a common intraneural bundle.

(2) The relation of the nerve trunk to the triceps muscle is important.

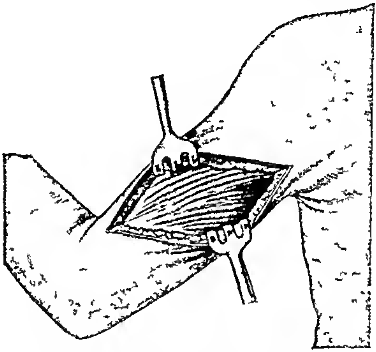

Fig. 267.—Exposure of the musculo-spiral nerve. Incision through the outer head of the triceps.

As the nerve leaves the axilla it turns outwards in front of the long head of this muscle to enter the upper part of the musculo-spiral groove; in the groove it is covered by the outer head, and at first indicates the line of natural separation between the long and inner heads. In the lower third of the arm its intimate association with the triceps ceases, and its course is now the line of cleavage between the brachialis anticus and the supinator longus muscle, where it passes through the external intermuscular septum.

(3) The superior profunda artery and veins cling closely to the sheath of the nerve over practically the whole extent of its course and, while constituting a useful anatomical guide, often add to the embarrassment of the operator when the deep scarring is well marked.

Position of the patient.—(1) For the conventional exposure in the lower two thirds of the arm the limb is drawn across the chest (2) when the nerve is to be displayed just below the axilla the arm must be abducted at right angles to the body

Skin incision.—This runs obliquely across the postero lateral aspect of the upper arm beginning just above and behind the *deltoid* insertion, and ending in the *antecubital* fossa a little below the external epicondyle (Fig 266) For the infra-axillary exposure, a separate incision on the mesial aspect of the upper arm will be necessary The combined incisions are required for gross lesions in which a formidable gap must be bridged

(1) **Infra-axillary exposure of the nerve**—The approach to the nerve behind the main vessels in the lower part of the axilla has already been described As the nerve runs over the latissimus dorsi towards the musculo spiral groove, it is joined by the superior profunda vessels which render the dissection somewhat difficult until ligated The three upper motor branches and the first sensory branch also tend to complicate the exposure The former should be delicately stripped up from within the nerve sheath, and carefully retracted A further obstacle is the inner head of the triceps, which is best circumvented by division of a few fibres of its origin The nerve-trunk is now cleared from the lower third of the axilla to the upper limit of the musculo-spiral groove Further distal exposure will necessitate bringing the arm to the side and across the chest

(2) **Exposure below the musculo-spiral groove**—The interval between the *brachialis anticus* and the *supinator longus* is defined and opened up at the level of the external epicondyle, and the nerve-trunk discovered lying rather deeply Closely affixed to its sheath are the small radial recurrent vessels, which must be separated and tied off The nerve is easily followed upwards to the lower end of the groove A large sensory branch (lower external cutaneous) is seen, lower down it demarcates the line of fusion between the adjacent borders of the supinator longus and triceps muscles The main trunk passes out of sight beneath the supinator longus, and here the small branch to this muscle should be identified

(3) **Exposure in the musculo-spiral groove**—In the upper part of the groove the line of the nerve indicates the natural cleavage between the *long* and *inner* heads of the triceps A fascial expansion forms a roof to the groove, which is covered still more superficially by the *outer head* of the triceps Both these structures must be divided in order to gain access to the nerve-trunk as it lies on the bone with the superior profunda vessels running above and to the outer side but clinging intimately to its sheath (Figs 267, 268) The lower motor branches are seen entering the triceps heads in the upper part of the wound, and the origin of the lower external cutaneous branch should also be displayed

Repair of the lesion —(1) **Difficulties** —Occasionally in spite of the fullest relaxation afforded by the exposure described end to-end apposition of the nerve stumps is not obtainable In such circumstances it is advisable to transpose the nerve-trunk to the front of the arm and thus gain at least an additional inch The operation of *anterior transposition* comprises the following steps (*a*) Exposure of the nerve in the upper third of the arm (infra axillary approach) (*b*) Exposure of the nerve in the lower half of the upper arm (*c*) Division of the nerve through the proximal bulb in the upper wound and

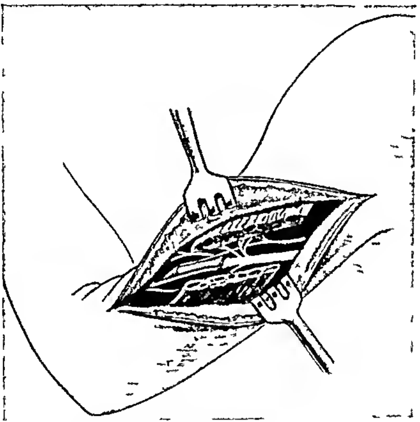

Fig 268 —Exposure of musculo spiral nerve in middle third of arm after division of outer head of triceps

through the distal bulb in the lower wound This leaves the injured segment *in situ* in the mass of scar occupying the musculo-spiral groove (Danforth and Stiles) (*d*) Oblique tunnelling of the brachialis anticus muscle from the upper to the lower wound fairly close to the bone (*e*) Displacement of the proximal and distal nerve stumps to occupy the tunnel (*f*) Trimming of the nerve-ends followed by suture

(2) **Nerve-bed** —The repaired nerve should be shut off from contact with the humerus by a muscle flap from the triceps Where there has

been an extensive destruction of the muscle a fascia lata sheet should be interposed

Closure of the wound.—The divided outer head of the triceps should be sutured, and the deep fascia restored as accurately as possible

Postoperative position of limb.—The elbow is slung in flexion with the upper arm close to the body The hand is bandaged on to a "cock up" splint in the physiological position of rest Free movement of the limb may be allowed at the end of two weeks

Operations on the Posterior Interosseous Nerve

Injuries of this nerve are uncommon The chances of successful operative repair are small for, from its origin from the musculo-spiral, the nerve has a very short course and immediately breaks up into a leash of fine branches

Exposure.—The lower end of the musculo-spiral nerve is first identified as it disappears beneath the supinator longus muscle The latter must be fully retracted after being freed along both its anterior and posterior borders The interval between the radial extensors and extensor communis digitorum is next opened up and the neck of the radius demonstrated, clothed by the supinator brevis The nerve enters the substance of this muscle at its upper limit, runs down between two definite layers and emerges below via a small tendinous arch At this level the proximal branches are given off By dividing the superficial fibres of the supinator brevis the parent nerve trunk is completely displayed

Operations on the Median Nerve

Indications. (1) *Subcutaneous injuries*—In *supracondylar* fractures the nerve is occasionally bruised or torn by the lower end of the forwardly displaced diaphysis Such lesions may co-exist with an ischæmic contracture (Volkmann)

(2) Lesions due to *penetrating wounds* are familiar both in civil and military surgical practice In the forearm the nerve is commonly damaged by particles of glass, and adjoining tendons are apt to be divided In gunshot wounds of the upper arm the brachial artery may also be injured, if an aneurysm develops, the nerve trunk almost invariably becomes adherent to the sac wall

Special anatomical features—In the upper third of the forearm a clear idea of the origin and distribution of the motor branches arising in the ante-cubital fossa is necessary A fairly constant scheme is as follows *

(1) *Uppermost branch to the pronator radii teres*—This is the first branch of distribution and, as a general rule, leaves the parent trunk just below the level of the internal condyle, but not infrequently may appear some little distance above this point Followed upwards within the sheath of the nerve, the branch is found to be continuous with bundles situated in the *lateral* half of the cross-section of the trunk Below, just before its entry into the muscle, the branch

* Linell *Journ Anat* Jan April, 1921 lv 79

divides into two twigs which supply the condylar and coronoid heads of origin The latter may occasionally receive its motor nerve as a separate branch

(2) *Middle branch*—A stout bundle arises from the antero-mesial aspect of the nerve trunk about 2 cm down the forearm From this leash individual branches are given off to supply the flexor muscles arising from the internal condyle The individual heads of origin are innervated by separate twigs formed by further subdivision

(3) *Anterior interosseous nerve*—The origin of this stout branch is seen after division of the pronator radii teres

(4) *Branch to the flexor sublimis digitorum*—In nearly 50 per cent of individuals the median gives off a fine branch in the lower part of the forearm to innervate that part of the flexor sublimis digitorum muscle which belongs to the index finger I have frequently seen this branch during operations on the median trunk

Exploration of the Median Nerve in the Upper Arm

Position of the patient—The arm is supported on a rest at right angles to the long axis of the table

Skin incision—This lies along the course of the brachial artery beginning just above the antecubital fossa and ending at the level of the anterior fold of the axilla

Exposure of the nerve-trunk—The deep fascia is divided just posterior to the basilic vein which shows as a prominent landmark In the upper third of the arm the coraco brachialis muscle is demonstrated and its mesial border retracted The median nerve is at once found overlapping the brachial artery From this level it is easy to trace the nerve trunk downwards until the lesion is reached In the lower third of the arm the median basilic vein must be divided and tied and a few fibres of the bicipital fascia incised Here the nerve lies well away from the main artery The upper branch to the pronator radii teres muscle is usually visible some little distance above the level of the internal epicondyle The nerve trunk is now followed upwards to the level of the lesion

Repair of the lesion—In the presence of considerable scarring disentanglement of the nerve is a tedious procedure When the brachial artery is occluded the fibrous cord is always found closely adherent to the nerve-trunk Where resection and end to-end suture are necessary a change in position must be made In theory the upper arm should be brought close to the trunk with the elbow and wrist flexed But this would place the wound in an impossible situation for the operator Comfortable access to the wound and adequate relaxation are obtained when the upper arm is brought into flexion at the shoulder i e at right angles to the plane of the operating table A radical removal of scar tissue is necessary as a preliminary to replacing the repaired or freed nerve in an intramuscular bed fashioned from the biceps

Closure of the wound.—Reconstruction of the deep fascia should be attempted

Postoperative position of the limb.—A malleable metal splint is applied with the wrist in flexion, and the arm is supported by a sling, the elbow being fully flexed A week later, gentle stretching of the flexed joints is begun

Exploration at the Elbow and in the Forearm

Position of the patient.—As above

Skin incision.—The incision begins to the inner side of the biceps tendon, runs across the antecubital fossa, and follows the midline of the forearm as far as required

Exposure of the nerve at the elbow.—The bicipital fascia is divided and the median basilic vein tied The nerve-trunk should be found at the level of the internal epicondyle, and the uppermost motor branch identified The antecubital fossa is opened up by retracting the lateral edge of the pronator radii teres and the nerve trunk followed until it disappears beneath the superficial head of this muscle The *ulnar artery* comes into the field close to the nerve, which is related even more intimately to the venæ comites of this vessel At this stage the second motor branch a stout twig which arises from the antero mesial aspect of the parent trunk, is demonstrable The anterior interosseous branch is hidden lower down by the pronator radii teres It is often advisable to divide the superficial pronator fibres freely in order to gain adequate room this can be done without imperilling its nerve supply Where the scarring is extensive the whole pronator should be sacrificed without hesitation Where the lesion accompanies a supracondylar fracture the nerve-trunk, unless completely divided often becomes adherent to the irregular margin of the lower end of the shaft

Exposure of the nerve in the forearm.—The nerve is situated deeply in the upper half of the forearm, and at this level troublesome hæmorrhage may be encountered

(1) Upper third —It is always advisable to isolate the nerve trunk in the antecubital fossa before attempting to define it in the angle between the lower border of the pronator radii teres and the flexor carpi radialis The radial border of the latter is the correct guide, and here the nerve lies at a considerable depth, covered by the radial head of the flexor sublimis digitorum This structure must be cautiously divided and the nerve gently freed from its bed The fragile venæ comites of the *radial artery* are here in close relation, and are apt to tear

(2) Lower two-thirds —The relation of the nerve to the flexor carpi radialis has already been indicated Lower down, the nerve trunk passes behind this obliquely running structure, and appears to become almost completely enveloped in a muscular tunnel provided by the

flexor sublimis digitorum (Fig 269) The special motor branch which supplies the index portion of the flexor sublimis may be seen at this stage Nearer the wrist the nerve approaches the surface, and is easily displaced after incision of the deep fascia along the ulnar border of the flexor carpi radialis tendon The palmaris longus tendon when present lies almost exactly over the nerve trunk At the wrist the nerve passes deeply under the anterior annular ligament In an extensive lesion it is often necessary to divide the roof of the carpal tunnel and follow the nerve into the palm

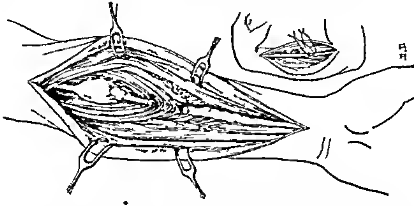

Fig 269 —Exposure of median nerve in the lower two thirds of forearm.
Illustrates the splitting of the belly of the flexor sublimis digitorum The lesion depicted is of the complete anatomical type

Repair of the lesion —The position of relaxation which facilitates end to-end suture is most awkward for the operator but with the limb fully rotated out at the shoulder the wound is not entirely hidden Additional relaxation may be obtained by stripping up the proximal motor branches and also by displacing the nerve in front of the pronator radii teres In the upper third of the forearm a suitable intramuscular bed is readily fashioned In the lower third the absence of muscular tissue and the proximity of the nerve to tendons render the surroundings more unsuitable A convenient method of shutting off the nerve is to turn down a pedicled flap from the belly of the flexor sublimis digitorum

Closure of the wound —Accurate restoration of the deep fascia is often impracticable In the upper third the muscle bellies fall naturally together and cover the repaired nerve If there is an extensive loss of deep fascia in the lower third a muscular flap or free fascial graft must be used to protect the nerve from the skin flap

Postoperative position of the limb —This has already been described

Operations on the Ulnar Nerve

Indications for operation —(1) *Penetrating injuries* provide a considerable number of lesions demanding exploration Gunshot injuries

may occur at any level but in civil injuries the nerve is usually divided in the lower third of the forearm in company with adjoining tendons

(2) *Subcutaneous injuries* are common in the region of the elbow where the nerve is unusually vulnerable Lesions in the post-condylar groove are conveniently included under the heading *traumatic neuritis*, of which there are three main clinical types (*a*) Lesions associated with *recent* fractures of the lower end of the humerus and dislocations of the elbow (*b*) late ulnar palsy and (*c*) recurring dislocation of the nerve

Special anatomical features —The proximal branches of distribution which arise in the region of the elbow joint are of great surgical importance, and may be described in the order of their origin

(1) *The articular branch to the elbow joint* —This usually arises above the level of the internal epicondyle and after a very short course enters the capsule of the joint on its postero mesial aspect

(2) *Branches to the flexor carpi ulnaris* —These present considerable variations, but commonly there are *two* main twigs which leave the main trunk just before it passes between the two heads of the muscle The upper branch supplies the *olecranon head* and has a very short course, the lower branch enters the *condylar head* at a lower level An additional supply to the condylar head is present in about 20 per cent (Linell) This twig has a particularly long extra muscular course

(3) *Branch to the flexor profundus digitorum* —This branch leaves the ulnar trunk after it has passed under cover of the flexor carpi ulnaris It is much stouter than the branches arising above it, and it has an extramuscular course of at least 1 inch

Exploration in the Upper Arm

Position of patient.—The arm is abducted and supported as in an exploration of the median nerve

Skin incision —The nerve lies immediately posterior to the line of the median nerve and brachial artery The incision extends from the elbow to just below the anterior axillary fold

Exposure of the nerve-trunk.—The basilic vein is the first guide, the fascial envelope being opened just behind it In the upper part of the wound the median nerve usually appears, and is a useful land mark The ulnar nerve is now found lying on the triceps and when traced downwards is seen to pass backwards away from the main artery and median nerve to reach the posterior compartment of the arm In the region of the internal epicondyle the nerve is exposed after dividing the deep fascia just behind the internal intermuscular septum The fine accompanying vessel (inferior profunda) should be carefully separated from the nerve-sheath and preserved

Repair of the lesion.—The local conditions relating to scar and the nerve-bed in the upper arm have already been emphasized The position of full relaxation differs from the one which is appropriate for the median nerve, in that the *elbow* must be maintained in *extension* In

grave lesions the amount of relaxation afforded by this position is often insufficient and it is necessary to transpose the nerve to the front of the elbow in order to take advantage of flexion of the joint (Fig 270)

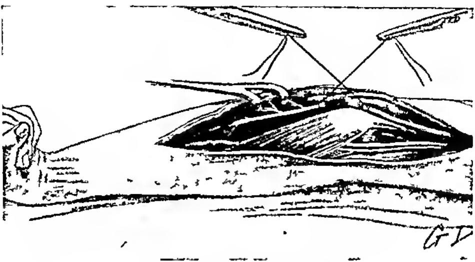

Fig 270 —Exposure of ulnar nerve in upper arm and upper two thirds of forearm
Illustrates failure to secure end to-end approximation with the elbow fully extended the wrist flexed, and the arm adducted to the side In such circumstances anterior transposition of the nerve is indicated

Exploration in the Region of the Elbow

This operation includes exposure in the lower third of the upper arm, in the post condylar groove and in the upper third of the forearm

Position of the patient —There are two alternatives (*a*) The arm abducted and supported at right angles to the body (*b*) the reversed position in which the limb is carried across the chest the upper arm being held vertical to the operating table with the elbow and wrist fully flexed This is simply the position of full relaxation of the nerve adopted at the beginning of the operation The position presents considerable advantages and has been employed by me as a routine for many years (Fig 271)

Skin incision —The incision begins in the lower third of the upper arm and passes behind the internal condyle into the forearm where the line of the nerve extends from a point midway between the epicondyle and olecranon to the radial side of the pisiform bone

Exposure of the nerve-trunk —The nerve is freed above the epicondyle and the fascia covering the post-condylar groove divided cautiously The nerve sheath is connected to the floor of the groove by filamentous strands When continued into the forearm the deep incision separates the fusion of the condylar and olecranon heads of the *flexor carpi ulnaris* After the muscular fibres are retracted the nerve is seen lying on the flexor profundus digitorum covered by a thin

semi transparent fascia In this dissection the proximal branches must be identified in order and carefully preserved

Repair of the lesion —In all lesions of the nerve in the post condylar groove the *repaired nerve should never be replaced in its original bed* but should be transposed to the front of the elbow

Exploration in the Forearm

The position of the limb and skin incision have been indicated In an exposure limited to the lower third of the forearm the natural approach to the nerve is in the interval between the flexor carpi ulnaris and flexor sublimis digitorum But in the upper third the two heads

Fig 271 —Exposure of the ulnar nerve in the region of the elbow
Note the reversed position of the limb and the skin incision

of the flexor carpi ulnaris are separated If this plane is followed in the middle and lower thirds of the forearm the fibres of the condylar head must be detached from the tendon of insertion

In the middle third of the forearm the ulnar artery joins the nerve and both structures lie in a common sheath The venæ comites adhere closely to the epineurium and are easily torn during separation The dorsal cutaneous branch of the nerve appears in the lower third

Traced downwards to the wrist the main trunk is found to pass close to the pisiform and to disappear into the palm under cover of the palmaris brevis

Anterior Transposition of the Ulnar Nerve

This operation is well established and is employed under the following conditions (1) In extensive lesions (particularly gunshot injuries) at any level as an aid to end to end suture (2) for all lesions in the

substance of the coraco-brachialis muscle where its first motor branch is given off. Both this nerve and the *circumflex* may be repaired if necessary in conjunction with lesions of adjoining trunks.

Operations on the Great Sciatic Nerve

Indications. (1) *Penetrating injuries.*—Sciatic lesions are common in modern warfare and are often accompanied by symptoms of severe irritation with conspicuous trophic phenomena. (2) *Sciatica* (sciatic neuritis).—Direct stretching of the nerve-trunk is an obsolete procedure which need not be described.

Special anatomical features.—(1) The external and internal popliteal elements are separate nerve-trunks from the origin of the sciatic nerve within the pelvis, but are usually included in a common sheath. (2) As the sciatic emerges from the sacro-sciatic notch it consists of three definite parts, viz. the external popliteal bundle, the internal popliteal bundle, and a leash of branches to the hamstrings. The

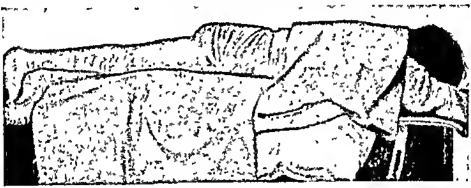

Fig. 273.—Position of patient for operations on sciatic nerve.
Note the extended position of the hip obtained by the adjustment of sandbags.

latter can be freed and stripped from the common trunk for some distance inside the pelvis. (3) A special branch of supply to the biceps cruris (short head) arises from the lateral aspect of the main trunk about the middle of the thigh.

Position of patient.—The patient lies fully prone. In dealing with extensive gunshot lesions the position of full relaxation should always be instituted at the beginning of the operation. For this it is necessary to place the hip in *hyperextension* by careful adjustment of sandbags. (Fig. 273.) Further relaxation will be obtained during the operation by flexing the knee.

Skin incision.—In the buttock this should begin over the sacro-sciatic notch, and should sweep downwards and outwards to a point mesial to the trochanter. From this level the incision is carried vertically downwards as far as necessary in the midline of the thigh.

Exposure of the nerve-trunk. (1) In the buttock.—The gluteus maximus fibres are split above and divided below towards the lower margin of the muscle Brisk bleeding occurs from small twigs of the gluteal and sciatic vessels No ill results follow the splitting of this extensive muscle but the alternative plan of detaching it partially from its insertion may be followed if preferred

Fig 274 Anatomy of complete exposure of the sciatic nerve *showing relation of nerve trunk* to biceps cruris muscle

Retraction of the thick fibres brings into view the nerve-trunk lying in its capacious sheath on the quadratus femoris Just below the notch the three distinct components—the external popliteal segment the internal popliteal segment and the leash of branches to the hamstrings—should be identified The latter can be stripped up to well within the pelvis if it is necessary to mobilize the main trunk to the utmost extent The inferior gluteal nerve which appears below the level of the pyriformis should be recognized and its branches to the gluteus maximus conserved Sometimes the two great divisions of the sciatic issue separately from the pelvis and are never conjoined

(2) In the thigh —Below the buttock the deep fascia is incised over the interval between the biceps and semitendinosus Lower down the semimembranosus forms the mesial boundary The small sciatic nerve is often a useful guide to this intermuscular interval The biceps crosses the line of the nerve and it is often necessary to free the muscle extensively before retraction is possible The nerve trunk lies on the adductor magnus *embedded in fat and the two main divi*sions are easily distinguished within the common sheath (Fig 274)

Repair of the lesion —In extensive gunshot injuries the *remains* of the nerve-trunk are usually incorporated in a dense scar which includes the hamstring muscles A considerable length of nerve trunk may need resection and the lesion may approach the irreparable standard When end to-end suture is possible only under conditions of extreme tension it is justifiable to use an absorbable stay suture

In more localized lesions one component of the sciatic trunk may be absolutely intact In such circumstances ' segmental suture' of either the peroneal or tibial division may be indicated The uninjured component then becomes looped The abundant muscular tissue of

the thigh and buttock makes the reconstruction of an adequate bed an easy matter

Closure of the wound—The gluteus maximus should be restored accurately and the retracted hamstring muscles brought together by suture of the deep fascia With the limb in the position of relaxation, closure of the lower part of the skin incision is apt to be awkward

Postoperative position of the limb.—The combination of hyper extension of the hip and full flexion of the knee is best maintained in a plaster-of Paris shell extending from the upper thorax to the middle of the lower leg (Fig 275) This shell should be made some days beforehand with the limb in the required position In it the patient

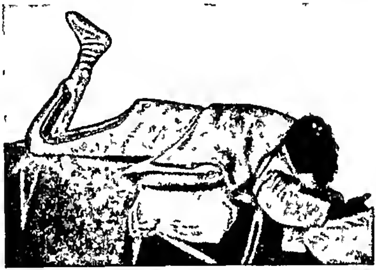

Fig 275 —Position of limb after suture of sciatic nerve
Shows the plaster cast which maintains hyperextension of the hip and flexion of the knee

is nursed on his face for the first 18 hours, and then turned on to the side As an alternative, the lower limb may be thrust through a gap in a sectional mattress, with the patient on his back Fixation methods improvised at the time of the operation mean added shock due to delay and extreme discomfort in postoperative nursing At the end of a fortnight the hip may be allowed to resume the ordinary position of slight flexion A week later gradual straightening of the flexed knee is begun

Operations on the External Popliteal (Peroneal) Nerve

Indications for exploration.—(1) Penetrating lesions (2) Severe traction lesions necessitating operative repair occasionally accompany such uncommon injuries as dislocation of the knee-joint or fracture of the upper end of the fibula

Position of the patient.—The patient lies on his sound side, three-quarters prone, with the hip and knee flexed

Skin incision —This follows the line of the biceps tendon in the thigh and ends behind the neck of the fibula The incision may be prolonged over the upper part of the anterior compartment of the leg if the terminal branches of the nerve are to be freed

Exposure of the nerve-trunk —After division of the deep fascia the biceps is retracted and the nerve trunk at once comes into view Traced downwards it is seen to disappear underneath the upper part of the peroneus longus muscle and to divide into the anterior tibial and musculo-cutaneous nerves Just above the fibular neck the large lateral cutaneous branch should be demonstrable

Repair of the lesion —When the lesion is close to the neck of the fibula repair may involve separate suture of the anterior tibial and musculo cutaneous nerves to the parent trunk To obtain sufficient relaxation it may be necessary to expose the sciatic trunk for some distance in the thigh and strip up the external popliteal component A suitable nerve bed is not always forthcoming but a flap from the peroneus longus or outer head of the gastrocnemius is the most useful shield End to end suture is carried out with the knee flexed

Position of the limb after operation —This is identical with the one described for the sciatic nerve except that extension of the hip is rarely necessary

Operations on the Internal Popliteal (Tibial) Nerve

Indications for exploration —Operations on this nerve are uncommon and are almost entirely limited to penetrating injuries Occasionally the nerve lesion may be associated with an aneurysm of the popliteal artery

Position of the patient —This is the same as for the sciatic nerve

Skin incision —A midline incision over the whole extent of the popliteal space is used

Exposure of the nerve-trunk —In the upper part of the popliteal space the nerve is found immediately after incision of the deep fascia Lower down it lies over the thick walled popliteal vein and passes out of sight where the two heads of the gastrocnemius converge The stout motor branches supplying this muscle show up conspicuously Where the perineural scar is abundant or an aneurysm is present disentanglement of the nerve from the vessels is difficult

Operations on the Posterior Tibial Nerve

Indications —This nerve is rarely explored Exposure in the upper part of its course is the natural prolongation of the internal popliteal exploration In the lower part of the leg the nerve comes nearer the surface

Exploration in the Upper Two thirds of the Leg

Skin incision —This begins in the middle of the popliteal space and is continued downwards in the midline of the leg

Exposure of the nerve-trunk —The nerve is covered by (a) the muscle bellies of the gastrocnemii (b) the soleus and (c) the fascial roof of the deeper compartment of the leg These various layers must

be split vertically and retracted fully The nerve is in close relation to the posterior tibial artery, at first on its mesial side then crossing it to reach to its outer side In the upper part of the wound the motor branches to the deeper muscles should be isolated and guarded

Exploration in the Lower Third of the Leg

The skin incision runs just behind the mesial border of the tibia The edge of the soleus is defined and retracted after division of the deep fascia The nerve and artery lie underneath a fascial roof in the interval between the flexor longus digitorum and the flexor longus hallucis In the lower part of the field the tendon of the tibialis posticus comes into view

ANTERIOR CRURAL, ANTERIOR TIBIAL, MUSCULO CUTANEOUS, AND PLANTAR NERVES

For obvious reasons, lesions of the *anterior crural* nerve-trunk in the thigh at the level of its division into its multiple branches belong to the irreparable class Exploratory operations on the anterior tibial, musculo cutaneous and plantar nerves have little special interest or practical importance

OPERATIONS FOR CRANIAL NERVE INJURIES

In injuries of the cranial nerves, with the exception of the 7th and 11th, the problem of direct operative repair does not arise The *spinal accessory* (11*th*) is easily exposed, but as in the majority of lesions there is considerable loss of nerve substance, the resulting gap can rarely be closed Reference has already been made to the treatment of lesions of the *facial* (7*th*) nerve by various types of nerve anastomosis, operations which, though possibly only of academic interest, may now be described

Facio-hypoglossal Anastomosis

Skin incision.—A fairly generous incision extending from the tip of the mastoid to below the great cornu of the hyoid bone is required

Exposure of the facial nerve.—The deep fascia is divided, and the sterno mastoid and posterior belly of the digastric are defined The styloid process is the most important landmark, and is exposed by dissecting deeply underneath the lower pole of the parotid gland The facial nerve is now sought as it emerges from the stylo-mastoid foramen If intact, it is divided by a tenotome as high up as possible, but if already severed within the facial canal, the peripheral stump is pulled out of the foramen

Exposure of the hypoglossal nerve.—The two main guides are the transverse process of the atlas and the occipital artery, around which the nerve hooks The nerve is freed and approximated to the facial

Anastomosis.—The hypoglossal nerve may be divided completely, or through two-thirds of its cross-section The former is preferable in spite of the resulting sacrifice of one half of the lingual musculature The proximal end is then sutured to the distal stump of the facial, the finest material being employed

Closure of the wound.—As the operation is almost invariably conducted in an area free from scar, a suitable bed is readily provided.

Facio glosso pharyngeal Anastomosis

The skin incision described above is used, and the facial nerve exposed and its distal end prepared in the usual way The glosso pharyngeal nerve is found beneath the upper and posterior part of the hyoglossus muscle and is divided completely just proximal to its lingual branches End to end suture between the two nerves is carried out

Exposure of the glosso-pharyngeal nerve.—The glosso-pharyngeal nerve is divided close to the posterior border of the hyoglossus muscle, beyond the origin of the branch to the pharyngeal plexus Difficulty may be experienced in isolating the nerve, and much time can be saved by defining the external and internal carotid vessels and exposing the nerve between them whence it can be followed distally to make the division

The posterior belly of the digastric has been exposed already in the isolation of the facial trunk and the vessels should first be defined below this muscle and the latter then retracted upwards The styloid process with its attached muscles can now be demonstrated The trunk of the 9th nerve is found just under cover of the lower border of the stylo pharyngeus and followed carefully forwards between the carotids to the posterior border of the hyoglossus

In a thick necked patient the dissection may be very difficult and tedious if the anatomical landmarks are not carefully defined at the outset

A similar exposure can be used to evulse the nerve in glosso-pharyngeal neuralgia but the dissection must be carried up nearer the base of the skull and the nerve pulled out from the jugular foramen *

Nerve grafting in Facial Palsy

Nerve grafting has become the method of choice in destructive lesions of the facial nerve in the Fallopian aqueduct The technique generally used is based on the pioneer experimental and clinical work of Ballance and Duel The steps of the operation are as follows —

(1) **Exposure of the nerve.**—The nerve is identified at the stylo mastoid foramen and followed upwards To expose the trunk proximal to the injury a radical mastoid operation is necessary The nerve ends are freed and all intervening scar and granulation tissue is removed

(2) **Insertion of the graft**—A graft of sufficient length equal in calibre to the facial nerve is taken from the middle cutaneous nerve of the thigh and is implanted in the gap A single sheath suture at each end is sufficient but if the graft lies snugly the sutures may be dispensed with

VI POSTOPERATIVE TREATMENT

Early stages—Until the wound is healed the limb is usually retained in the position adopted at the end of the operation This, however, should not be a period of total inactivity In the *upper limb* movements of the fingers are encouraged after a few days, and if necessary light massage may be applied to available surfaces After removal of the

* See *Lancet* August 22, 1931 ii, 397

sutures a greater surface area is exposed for physical treatment. Stretching of the flexed joint is begun, on the average, at the end of two weeks. In the *lower limb*, after suture of the sciatic nerve, stretching is often impossible at a very early date, and must always be carried out with great caution.

Later stages.—The patient should be given the benefit of a full physiotherapeutic regime. It must be realized, however, that such treatment has no direct influence on the regeneration of nerve fibres, but simply helps to improve and conserve the nutrition of the tissues controlled by the injured nerve. Physical treatment may be classified under two headings:—

(1) Postural treatment.—The paralysed muscles must be retained in the position of *moderate relaxation* by some form of light and comfortable splinting. The correct posture also prevents the development of contractures. The appropriate positions for the various nerves are given in the following table:—

Nerve	Physiological Position of Muscle Relaxation	Mode of Retention or Splinting
Brachial plexus	Abduction at shoulder, flexion at elbow. Hand in position of physiological rest	Shoulder abduction splint or axillary muff
Musculo-spiral nerve	Hand in position of physiological rest, viz., wrist dorsiflexed, fingers very slightly flexed at metacarpal and interphalangeal joints, thumb abducted and extended (cricket ball or bottle grasping position)	Long cock-up splint for nightwear. Short cock-up splint during the day
Median nerve	Hand in position of physiological rest	No splinting necessary
Ulnar nerve	Hand in position of physiological rest	No splinting necessary except for correction of an already developed claw contracture. It is usually sufficient to apply a corrective splint at night only
Sciatic nerve	Foot dorsiflexed at right angles to leg	For night wear a simple rectangular metal splint. Walking appliance: single or double short steels with some form of uplifting spring or foot-drop stop

(2) Nutritional treatment —The following measures should be prescribed as a routine —

(a) *Heat* —The paralysed limb should be kept warm Woollen gloves, sleeves or extra socks are essential in cold weather The limb should be adequately warmed before the application of massage or electrical treatment The methods of obtaining hyperæmia in common use are (i) dry heat—radiant heat baths, paraffin wax baths, diathermy (ii) moist heat—simple hot water baths or whirlpool baths In irritative lesions, however, heat is contra indicated pain and hyperæsthesia being relieved only by intense cold e g evaporating lotions and the like

(b) *Massage* —In the earlier stages this should be superficial and carried out with gentleness As recovery sets in the depth and vigour should be increased

(c) *Electrical stimulation* —The denervated muscles should be made to contract at each sitting, care being taken to avoid fatigue At first the galvanic current only will be used, in the recovery stage faradic excitation is substituted as soon as an adequate response is noted The stimulation must be accurately applied to the affected muscles, and leakage of current through to the antagonists avoided

(d) *Muscle re education* —True re-education is practised when definite voluntary power has appeared and for some time is best combined with regular faradic stimulation The recovering muscles are re educated from what is known as the zero position where the effect of gravity is eliminated and the load is nil As voluntary power increases the load and range of movement are increased *pari passu* Re-education may also be used in training a patient to develop " trick or ' substitute movements before the onset of true recovery Where imperfect regeneration of the injured nerve is anticipated such trick movements have considerable economic value

(e) *Exercises and curative work* —In the final stages of recovery the development of co-ordinated and purposive movements is the most important therapeutic problem This end is best attained by carefully prescribed exercises Where patients are treated in larger numbers handicraft training in curative workshops is a most valuable adjunct

VII RESULTS OF OPERATIONS FOR THE REPAIR OF NERVE INJURIES

In judging the true end results of operations for the repair of peripheral nerve injuries it is necessary to make a clear distinction between two standards of assessment, the physiological (or neurological) and the functional (or economic) The former represents the amount of conductivity which has been restored to the nerve as measured by the usual clinical and electrical tests The latter denotes the capacity which the limb has regained apparently as the result of the operation The two standards do not necessarily run parallel, A good functional result may accompany a poor neurological result, on the other hand

with a satisfactory or almost perfect neurological result there may be little improvement in function The reasons for such discrepancies are not far to seek A complete lesion of a peripheral nerve may cause little practical disablement in certain individuals Thus the elimination of the function of the ulnar intrinsic muscles of the hand is of importance only to those whose occupation demands the finer hand movements This may be contrasted with the more serious disablement which is always seen in a complete lesion of the median nerve, where the anæsthesia of the index finger alone impairs the capacity of the hand for most types of work Again the successful repair of the nerve, even if restoration of conduction and function go hand in hand, may be of no practical value to the patient if other structures are seriously damaged Finally, delay in recovery may be due to psychical causes It is now recognized that nerve recovery requires a much longer time than used to be thought, and in almost every case the period will be one of years rather than months The age of the individual is also an important factor recovery being much quicker and more complete in young individuals, in whom normal growth is still active

Results of End-to-end Suture

Primary suture.—*Perfect recovery of* both motor and sensory functions may follow the immediate repair of a clean-cut division of a nerve where aseptic wound healing has occurred Such results, however, are exceptional

Secondary suture.—The results on the whole tend to be disappointing Of the factors which influence the standards of recovery the following are the most important —

(*a*) *Topographical confusion* —A certain amount of "shunting" of regenerating nerve-fibres along alien channels in the distal trunk occurs after most nerve sutures Thus, motor fibres grow down sensory sheaths, sensory down motor sheaths pain fibres reach 'heat" endings, and so on In lesions in which extensive resection is necessary, a considerable disturbance of the intraneural pattern results Such regenerative chaos is the outstanding cause of the imperfections of the neurological and functional results of nerve suture (*b*) *Wound infection* —The role of infection is well demonstrated in the changes which occur in the nerve-trunk itself Above the suture, an interstitial neuritis may extend for many inches At the site of suture, cicatricial shrinkage may result in the obliteration of nerve-fibres which have re-established communication with their end organs Below the suture, the axis cylinders often remain imperfectly myelinated The sum of such changes means scanty re-innervation of motor and sensory structures (*c*) *The time factor*—i e the delay between the injury and the repair After a certain optimum period, arbitrarily estimated at three years, recovery tends to be less certain and less complete The harmful effects of long delay depend chiefly on degenerative changes in the muscles and other peripheral tissues, and to a lesser extent on retrogressive changes in the central nerve-cells (*d*) *Anatomical situation*

of the suture —Sutures in the proximal part of the limb show a higher percentage of recovery than sutures in the distal part

Comparison between the different nerves Musculo spiral nerve — All statistics show that this nerve heads the list of recoveries whether judged from a qualitative or quantitative standpoint Almost perfect restoration of function has been observed in a considerable number of cases At the same time in the majority of these highly successful results the synergic action of the extensors of the wrist is lacking a deficiency which tends to disappear only after years of occupational use of the hand

Ulnar nerve —In this nerve the results are physiologically imperfect but not necessarily economically bad Complete restoration of function in the ulnar intrinsic muscles of the hand appears to be unknown whilst full sensory recovery is also extremely rare The average sensory result involves the restoration of protopathic sensibility alone Many individuals with complete lesions of the ulnar nerve have been known to be capable of engaging in laborious occupations such as dock labouring coal mining and so forth But the musician the artist and the fine manual worker are seriously handicapped by the in complete recovery of the muscles of the hypothenar eminence the interossei and the adductors of the thumb

Median nerve —The results in this nerve are uniformly disappointing chiefly owing to the inadequate recovery of sensibility This nerve illustrates very beautifully how co-ordination in finer movements is dependent on the complete restoration of the paths for all types of afferent stimuli At the very best there is little more than full proto-pathic function whilst in a considerable proportion of operations no sensory recovery is seen Another type of relative failure is occasionally seen after suture of the median nerve viz the recurrence and per sistence of inveterate pain and hyperæsthesia

Sciatic nerve —Here the neurological and economic results are con-sistently poor No case is on record where recovery has been demon strated in the intrinsic muscles of the foot The type of sensory restoration on the average is exceedingly defective and in many patients constitutes a source of danger owing to the tendency to traumatic ulceration in the foot The earlier and more complete recovery seen in the calf muscles as compared with the anterior tibial group often determines a contracture in patients who lack post operative supervision As in the median nerve irritative phenomena are occasionally seen In a not inconsiderable proportion of gunshot injuries of the sciatic nerve after successful suture and the appearance of partial motor and sensory recovery amputation of the limb is necessary

External popliteal nerve —The percentage of complete failures is high but on the other hand very complete recoveries have been described In uncomplicated lesions the economic capacity of the individual provided with an efficient walking apparatus is very satisfactory

Of the results of secondary suture of the less commonly injured nerves the information is too scanty to merit a detailed discussion

Results of Neurolysis

It is often difficult to define how far a neurolysis has brought about the recovery which follows the operation In many pure compression lesions, removal of the compressing agent is rapidly followed by the re-appearance of both conductivity and function This means that the nerve-block has not been due to actual degeneration of axis cylinders The effect of a neurolysis under these conditions is to eradicate the trauma caused by the repeated stretching or friction of the anchored nerve during the natural movements of the part Where a compression lesion has been in existence for some time, and degeneration has occurred on a considerable scale, formidable obstacles to spontaneous regeneration are situated in the interior of the nerve-trunk—i e interstitial fibrosis Thus the elimination of the cause of the trauma at a late stage will not necessarily restore function This sequence is shown quite clearly in the results of the operative treatment of brachial neuritis due to a supernumerary cervical rib In 81 cases recorded by Sargent,* in which muscular atrophy (intrinsic muscles) was the predominating sign, full recovery of bulk and strength in the affected muscles was seen in 12 only

Statistics Illustrating Operation Results

Sherren (London Hospital), 1908 Civil injuries 71 operations *Primary suture*, 50 operations In all, motor function regained and restoration of protopathic sensibility All cases uncomplicated by suppuration, and *observed for a long period, regained perfect sensation*

Secondary suture, 21 operations Motor recovery in all Sensory recovery imperfect

Dumas (Paris) 1917 (*Bull et Mem Soc de Chir*, June 5 1917) 115 operations on the musculo spiral nerve (war injuries) Evidence of recovery in 42%, of regeneration in 65 2%

Tinel (Paris), 1918 109 operations (end to end sutures and nerve grafts) on various nerves (war injuries) Complete recovery in 20%, complete failure in 18%, improved, 66%

Stracker (Vienna), 1919 (*Beit z klin Chir*, 1919 cxvi, Heft 2) 238 operations, miscellaneous nerves (war injuries) Standard of recovery, the number of muscles re innervated *End to end suture*, 147 operations improved, 75% (at least one muscle showing recovery) cured, 18% (all muscles showing recovery)

Neurolysis 91 operations recovery in at least one muscle, 89%, recovery in all muscles 81%

Stopford (Manchester), 1920 (*Brain* May 1920) 271 operations (war injuries) performed by various surgeons Standard of recovery neurological *End to end suture* Upper arm, recovery of varying types in 88% failures (complete) 12% Forearm, recovery in 76%, failures, 24% Lower limb, recovery in 85% failures, 15%

* *Brain* 1921 xliv 72

Forrester-Brown (Edinburgh), 1920 (*Brit Med Journ*, Sept 25 1920) 275 operations (war injuries), performed by Stiles and the reporter Standard of recovery, neurological *End to-end suture* 158 operations Complete recovery, 29%, complete sensory recovery, 19%, complete trophic recovery, 21%, incomplete recovery of all three functions, 50% Total complete recovery seen in 5 median nerve sutures and 8 musculo spiral nerve sutures Comparison between different nerves Median nerve, 50% complete motor recovery, 28% complete sensory recovery Ulnar nerve, 17% complete motor recovery, 13% complete sensory recovery Musculo spiral nerve 62% complete motor recovery, 33% complete sensory recovery.

Neurolysis, 117 operations 43% full motor recovery, 19% full sensory recovery

Platt (Manchester), 1921 150 operations (war injuries) traced out of 307 operations (Interim results in the majority) *End to-end suture* Standard of recovery clinical estimation of motor and sensory conduction Recovery of varying types seen in 118 cases, 79%, failures (complete) seen in 32 cases, 21%, standard of failure no sign of reappearance of conduction after one year or longer

Results in more important nerves *Musculo spiral nerve*, 35 operations recoveries 26, failures 9 In 5 of the failures the posterior interosseous nerve was sutured to the musculo spiral trunk *Ulnar nerve*, 47 operations recoveries 41, failures 6 (forearm 3, upper arm 3) Suture after anterior displacement in 16 *Median nerve*, 30 operations recoveries 27, failures 3, all in forearm *Sciatic nerve*, 25 operations recoveries 18, failures 7

External popliteal nerve, 9 operations recoveries 4, failures 5 In 3 of the failures the anterior tibial and musculo-cutaneous nerves were sutured to the main trunk

Operations for causalgia *Median nerve*, 14 operations in 11 patients resection and suture 11 (2 on the same nerve) success (immediate complete relief of pain) 9, failure (incomplete relief) 2 Neurolysis 2, failure in both subsequent resection and suture with complete success Injection of quinine and urea 1 incomplete relief *Sciatic nerve*, 11 operations total resection and suture 9 success 9, segmental suture of internal popliteal element 1, success 1 neurolysis 1, success 1

Stopford (Manchester), 1923 Unpublished figures, gunshot injuries *True end results* as illustrated in the type of recovery seen in 157 suture operations In the majority of these cases the period of postoperative observation has extended over three years or more In all, the neurological syndrome has apparently reached a final and stationary stage The standard of assessment is neurological, the motor recovery being recorded in terms of voluntary contraction

Musculo spiral nerve 37 cases

Recoveries in terms of motor function —

Proximal muscles	Supinator longus Extensor carpi radialis longior Extensor carpi radialis brevior
Distal muscles	Extensor carpi ulnaris Extensor communis digitorum Extensor minimi digiti Extensor ossis metacarpi pollicis Extensor brevis pollicis Extensor longus pollicis Extensor indicis

Proximal muscles plus distal muscles (complete)	20
Proximal muscles plus distal muscles (partial) (Extensor brevis pollicis lacking in all)	16
Proximal muscles only	1

In two cases of complete recovery the interval between the date of injury and the time of operation was three years and two years respectively. In many of the complete recoveries the extensors of the wrist do not function synergically.

Ulnar nerve—38 cases (upper arm 19, forearm 19)

Proximal muscles	Flexor carpi ulnaris Flexor profundus digitorum
Distal muscles	Ulnar intrinsics of the hand

A Upper arm

Motor recovery	Proximal muscles plus distal muscles (partial)	12
	Proximal muscles only	7
Sensory recovery	Restoration of protopathic sensibility in	9
	Protopathic plus partial restoration of epicritic sensibility in	4
	No sensory recovery in	6

B Forearm

Motor recovery	Hypothenar muscles alone	8
	Hypothenar plus one or more of the intrinsics	9
	First dorsal interosseous alone	1
	No motor recovery	1
Sensory recovery	Protopathic plus epicritic (partial)	9
	Protopathic alone (complete 3, incomplete 3)	6
	Complete sensory recovery	1
	No sensory recovery	3

Median nerve—43 cases (upper arm 22, forearm 21)

Proximal muscles Pronator radii teres, wrist flexors and long finger flexors

Distal muscles. Median intrinsics of the hand.

A Upper arm

Motor recovery	Proximal muscles plus distal muscles (partial)	7
	Proximal muscles alone	15
Sensory recovery	Protopathic alone	11
	Protopathic plus epicritic (partial)	6
	No sensory recovery	5

B Forearm

Motor recovery	Thenar muscles	9
	No motor recovery	12
Sensory recovery	Protopathic alone	9
	Protopathic plus epicritic (partial)	10
	No sensory recovery	2

Sciatic nerve—27 cases

Motor recovery	Internal popliteal plus external popliteal muscles	20
	Internal popliteal alone	7
Sensory recovery	Protopathic alone (complete)	2
	Protopathic alone (incomplete)	14
	Protopathic plus *epicritic (partial)*	6
	No sensory recovery	5

External popliteal nerve—12 cases

Motor recovery	All muscles	6
	One or more muscles	6
Sensory recovery	Complete	4
	Protopathic alone	6
	No sensory recovery	2

Gosset (Paris) 1924 194 operations

SUCCESS OR MARKED IMPROVEMENT

NERVE	NEUROLYSIS	SUTURE
	per cent	per cent
Musculo spiral	95	45 to 55
Median	47	44
Ulnar	38	17
Sciatic—trunk 1917	55	85
1920	—	40
Sciatic—external popliteal	66	60
Sciatic—internal popliteal	—	10 to 50

Frazier (Philadelphia) 1924 496 operations (war injuries)

NERVE	RESULT GOOD	RESULT MEDIOCRE	NEGATIVE
	per cent	per cent	per cent
Brachial plexus	33	37	29
Musculo spiral	23	30	46
Median	58	28	14
Ulnar	12	55	31
Sciatic	25	41	33
External popliteal	31	52	16
Internal popliteal	46	46	8

CHAPTER XI

OPERATIONS ON BLOOD-VESSELS

By G. GREY TURNER

Surgical anatomy.—The walls of arteries are composed of three coats. The external or tunica adventitia consists of a network of elastic fibres and connective tissue. In this coat the blood-vessels and the network of sympathetic fibres supplying the artery are found. It is only loosely attached to the middle coat, or tunica media, which is the main framework of the vessels, being composed of strong elastic fibres with a lesser proportion of plain muscle, both closely bound together with connective tissue. The inner coat or intima is formed by a layer of elastic tissue supporting the smooth elongated endothelial cells which line the vessel.

All vessels lie in a bed of loose cellular tissue, which acts like a bursa around them and permits their free movement. The arteries are not only in a state of tension or tonus as regards their lumen but as regards their length, for they retract to a considerable extent when cut across. This retraction is associated with contraction of the lumen at the cut ends and is an important factor in the natural arrest of hæmorrhage.

The arteries of the limbs receive their nerve supply through sympathetic fibres which reach them by continuity with the plexuses on the great vessels of the trunk. But the supply is reinforced at various levels throughout the limb by post-ganglionic fibres which travel to the vessels *via* the peripheral nerve-trunks. The whole mechanism is regulated from the vaso-motor centre in the medulla which in turn is subject to influences from the higher cerebral centres. For the most part, the vaso-motor nerves are constrictor in function, but there is probably an active though not nearly so powerful vaso-dilator mechanism.

The veins are constructed on the same general plan as the arteries except that the three coats are much thinner. The inner coat is less easily ruptured and the middle coat contains a smaller proportion of muscular tissue. A characteristic feature is the presence of a system of valves which prevent reflux of blood. Each valve consists of two semilunar flaps attached to opposite sides of the vessel wall, each with a small sinus on its cardiac side. The distension of these sinuses closes the valve and prevents regurgitation. When the veins are chronically distended the valves are rendered incompetent. Valves are absent from the superior and inferior venæ cavæ and from the pulmonary veins, as well as from the portal vein and its tributaries. They are very scanty in the veins of the lower part of the rectum and in the iliac and common femoral veins. The circulation through the veins is greatly assisted by the pressure of the surrounding muscles.

GENERAL CONSIDERATIONS

The control of the circulation through a limb is necessary in many operations on the vessels of the extremities The method most generally satisfactory and to be employed whenever possible is the rubber tourniquet Much has been said about the harmful effects of the tourniquet these are mostly the result of long application but even when used for a short time during an operation damage may be caused to the nerve trunks of a thin upper limb That risk is reduced to a minimum by using the elastic bandage rather than the rubber

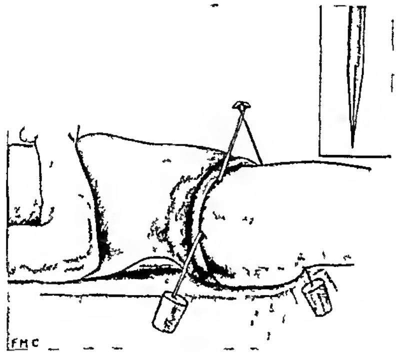

Fig 276 Wyeth pins retaining rubber tourniquet in position high up on the thigh Inset shows the point of the pin.

tube and by applying it just sufficiently tightly to arrest the arterial circulation rather than as tightly as possible as is sometimes advised Of all varieties of tourniquet the Esmarch s rubber bandage 2½ in wide is the most generally useful. Except for comparatively small upper limbs the pneumatic tourniquet has not been a success although the idea is thoroughly sound

Whenever conditions will allow the limb should be partially exsanguinated by elevation For this purpose it is held high above the body for three minutes As a result not only is the venous return assisted but as shown by Lister in 1879 there is also an active contraction in the arteries limiting the blood flow into the limb While the limb is still elevated the tourniquet is applied well above the area to be operated upon and the part is then slowly restored to body level If

the lesion is near the trunk it may be very difficult to apply the tourniquet or to keep it in position during the necessary manipulations In these circumstances Wyeth's pins (Fig 276) or the sling method, as shown in Fig 277, can be recommended In children or spare adults an elastic tourniquet applied around the trunk (the abdominal tourniquet) is usually efficient and is not likely to damage the intestine In mus-

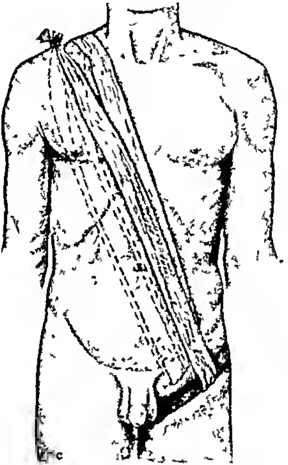

Fig 277 —Rubber tourniquet high on thigh retained in position with shoulder sling

cular or stout adults it is impossible to control the aorta in this way without exercising dangerous pressure

When a tourniquet cannot be used, temporary or provisional ligature of the main vessels may be employed It must be recognized that occlusion of the main vessel does not everywhere shut off the collateral circulation but, none the less in certain situations it provides a most effective control The artery chosen for ligature must be most gently handled, especially if it is likely to be degenerated The ligature material must be thick and must be so lightly tied that there is no

risk of injuring the intima No 5 catgut tied over a pad of gauze slightly larger than the artery to be occluded the tie of the ligature being placed over the gauze is very satisfactory and I have found that it will serve all purposes (Fig 278) Another plan is to use a piece of rubber tubing in place of the gauze pad or to slip a piece of split rubber tubing around the vessel and to tie the ligature round this Or the ligature may be of narrow (quarter inch) tape or soft rubber tubing Such a ligature may be passed round the vessel with an aneurysm needle the rather thick material being anchored to the eye of the needle with a fine catgut stitch Such a ligature need not be tied but crossed with sufficient tension in front of the vessel and fixed with a pair of artery forceps With a soft rubber tube used as a ligature, gentle traction away from the body often suffices to control the circulation in vessels of moderate size

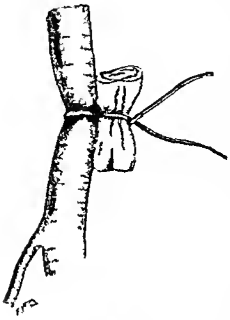

Fig 278 Temporary ligature tied over gauze pad

Temporary ligature in special situations — For large vessels occlusion clamps are not very satisfactory and are very apt to slip out of position In the neck temporary ligature may be required when operating for aneurysm or for the purposes of a trial arrest of circulation The common carotid—recognized by the absence of branches—will usually be selected The internal jugular vein should be carefully separated before attempting to pass the ligature For very vascular conditions in the upper limb the ligature should be placed on the third part of the subclavian artery In the lower limb occlusion of the common femoral does little to control hæmorrhage through the collateral circulation especially when this has become enhanced In the latter case it is far better to place the ligature on the common iliac which should be exposed by the abdominal route This is also the best course when dealing with vascular conditions about the buttock

Ligature of the main vessel of a limb —Quite apart from the risk of gangrene other considerations have stimulated surgeons to devise methods by which the main blood supply can be preserved Rutherford Morison used to say that a limb was never so good after the ligature of the main artery and Hogarth Pringle confirmed that opinion many of his patients complaining of some degree of permanent weakness in the limb The question is probably related to the degree of col

lateral circulation which has developed at the time the ligature is applied The lesson seems to be that in cases of injury every attempt should be made to repair or replace the damaged vessel In disease time should be allowed for the development of the collateral circulation and, when there is evidence that it has been established there need be less hesitation in applying the ligature I must confess that in dealing with aneurysms I have usually found it necessary to carry out excision with ligature of both ends of the vessel, but the results have been most satisfactory as regards absence of gangrene and subsequent function

Methods of preventing intravascular clotting—Until the use of heparin surgeons had to rely on (1) gentleness to avoid injury to the intima (2) liquid paraffin to protect needles and suture material, and (3) irrigation with anti coagulant citrate solutions As a result, much successful vascular surgery was carried out especially experimentally None the less, the risk of thrombosis was great and its onset often marred otherwise good results *Heparin* is an anticoagulant prepared from animal tissues and also synthetically Up to the present time its scarcity and expense have limited its application in practical work It is used in solution either locally to alter the clotting time in an area, or generally by continuous intravenous injection to increase the clotting time throughout the body Its advocates hope by its use, not only to prevent local clotting but to diminish the incidence of postoperative pulmonary embolism There is however, a considerable risk of spontaneous postoperative bleeding, and it should not be used intravenously until 4 to 12 hours after operation As yet the preparations and dosage are not standardized and are likely to be modified in the near future (1941) It is therefore necessary to be guided by the instructions issued with each of the several preparations on the market

It must never be forgotten that the most important criterion for success in vascular surgery is freedom from infection Holman (1937) summarizes the essential requisites as (1) absolute asepsis, (2) absolute hæmostasis and (3) the anatomical dissection of tissues

INJURIES OF ARTERIES

Arterial Hematoma and Traumatic Aneurysm

A wound of a large artery, or one of its branches, is followed by extravasation of blood into the tissues If the wound is not large and the surrounding structures are unyielding, the blood may be confined to the immediate vicinity, where it clots, forming a "circumscribed arterial hæmatoma" In other circumstances the blood may extravasate widely in the cellular planes up and down the limb, producing a large ill-defined swelling the "diffuse arterial hæmatoma" In either case the greater part of the effused blood coagulates and the wound in the vessel may become sealed off and the whole extravasation gradually absorb But, if the communication with the vessel

remains patent the central part of the hæmatoma forms a cavity constantly distended by the circulating blood The interior of the cavity develops an endothelial lining while its walls become thickened and organized The swelling acquires an expansile pulsation and a systolic bruit both of which either disappear or are much modified by pressure on the vessel on the proximal side of the sac This is the false or traumatic arterial aneurysm If the vein accompanying the artery is also involved in the wound a direct communication between the two may be established the aneurysmal varix or a sac may form between the two vessels when the condition is known as varicose aneurysm In each case the peripheral part of the hæmatoma becomes incorporated with the surrounding structures which are matted together in its wall The change from hæmatoma to aneurysm may come about almost at once or may be delayed for days or weeks The process is usually gradual but may be quite sudden In the early stages after injury there may be serious interference with the peripheral blood supply and gangrene may threaten As time passes the collateral circulation develops and there is usually greatly increased vascularity both of arteries and veins

Indications for operation —When the injured patient is seen in favourable surroundings such as a properly equipped hospital provides it is safer to interfere as soon as possible after the injury If the hæmatoma is increasing or the circulation of the limb is embarrassed or there are signs of infection arrangements must be made to operate in spite of the surroundings As soon as there are definite signs of aneurysm it means that operative interference will be required but this may be deferred until there is evidence that the collateral circulation is well developed On the other hand when the general condition is improving the local swelling subsiding and there are no signs of aneurysm the operation may be indefinitely postponed

The object of the operation is to expose the injured vessel and either to repair the rent to apply ligatures to excise a damaged portion or to bridge a gap by grafting or intubation Preservation of the vessel need only be considered in dealing with the largest arteries like the common carotid the subclavian the common or external iliac the femoral or the popliteal As a matter of actual experience there are very few occasions when conservative measures can be usefully attempted and the surgeon is usually only too thankful to be able to arrest bleeding by ligature

Technique —If seen within the first few hours and the general condition permits the injured vessel should be exposed by an adequate incision after the application of a tourniquet The clots which are easily displaced at this stage should be completely removed from the cavity in which they lie and a careful search made for the bleeding point with the aid of retractors and a good light

The special method adopted for dealing with the artery will depend upon the nature and extent of the injury If a wound of a branch

of the main artery be found, a double ligature will suffice Should, however, the main artery be the source of the hæmorrhage, an attempt should be made to preserve the circulation by arteriorrhaphy, or some other plan having this object in view, to which removal of the clot, by relieving tension, also contributes

This operation, especially where the hæmatoma is deeply seated, should always be regarded as serious, and the necessary steps should be taken to render the patient's condition as favourable as possible beforehand Blood transfusion may be necessary, and arrangements should always be made for this to be available, in case the patient should lose more blood at the operation

Loss of blood is not the only factor responsible for the tendency to gangrene, as any condition that reduces the blood pressure, such as cold or shock from multiple wounds, will have the same effect

Contusions and Wounds of Large Arteries

Contusions.—Whatever the degree of injury to an artery, whether by a direct blow or by stretching, the intima is always the first part to suffer Delorme ('Les Blessures des Vaisseaux"), as quoted by Sencert, describes three degrees of contusion of arteries (1) The intima only is damaged, and on opening the vessel linear tears are visible (2) The inner and middle coats are torn, the tear extending only partly round the vessel (3) There is a complete circular tear through the inner and middle coats, with retraction It must also be recognized that simple contusion of an artery or an injury in its vicinity may cause such a degree of spasm in the vessel that the distal pulse may be obliterated This spasm may be segmentary or it may affect the greater part of the vessel distal to the injury This is sometimes spoken of as "arterial stupor" The condition may last for as long as twenty-four hours Such injuries may also lead to thrombosis at the site, or a weakened area in the vessel-wall may subsequently give way, causing secondary hæmorrhage, or an aneurysm may develop

Of these various types, the most common appears to be the second The condition is diagnosed by the state of the distal pulse, which is either lost or weakened, the avascular appearance of the limb and the condition of the vessel when exposed at operation

Wounds.—Wounds of large arteries may be of several types (1) A large laceration with continuity completely interrupted, the injury being complicated by destruction of the neighbouring muscular and other tissues (2) A small wound, caused either by a missile, such as a piece of shell or flying glass or a stab, with considerable extravasation into the surrounding tissues, and much swelling (3) Gunshot wounds in which a missile passing close to the main artery has torn off one or more large branches

The surgeon's first aim is to prevent further loss of blood, and it must always be remembered that any bleeding-point which can be reached by the finger is under its control The tourniquet should be

avoided when possible and if it must be employed it should be removed at the earliest possible moment

The difficulties attending arteriorrhaphy the ideal method of dealing with a wounded artery are considered later When an important artery is divided completely and suture is impossible continuity may be temporarily restored by a silver or glass cannula if arrangements can be made for heparin administration

A proximal ligature should never be applied to a main trunk without careful examination of the wounded vessel unless indeed the condition is one of great urgency If such a ligature is used care must be taken to apply it as near to the wound in the vessel wall as possible in order to avoid interference with the collateral circulation The incision should be longer than for ligature of an unwounded artery because there may be great difficulty in locating the vessel on account of swelling from extravasation of blood a difficulty to which absence of pulsation will inevitably add A free exposure moreover renders it less likely that the surgeon will overlook a divided branch of the main vessel that may have retracted It should be borne in mind that the general condition is often serious from loss of blood and that transfusion plays an important part in the management

A very careful search for the actual bleeding point is essential and a ligature should never be applied to the main trunk until there is certainty as to the origin of the hæmorrhage for a large branch may be the source while the main artery itself is intact

A large vessel such as the external iliac may be *punctured* with a surgical needle an accident which has occasionally happened during an operation for the radical cure of hernia If recognized at the time the bleeding can be arrested by finger tip pressure which may be enough to allow contraction and permanent occlusion of the puncture If this does not succeed a single stitch may be applied in the adventitia across the puncture or a purse string suture may be required If oozing still persists a patch of fresh muscle held in position for a moment or two will adhere and almost certainly prove effective When delay has occurred a hæmatoma will probably have formed and must be dealt with as indicated in the previous section

Arterial suture —The treatment of wounds of arteries by suture is by no means new for it was practised by Surgeon Lambert of Newcastle upon Tyne as long ago as 1759

To secure successful results the following conditions are essential (1) perfect asepsis (2) a clean cut wound in the vessel wall without bruising (3) absence of tension at the line of suture (4) sufficient time to allow the surgeon to carry out the operation thoroughly (5) a minimum amount of surgical trauma (6) special precautions against clotting in the wounded vessel It will be seen from this enumeration why so few injuries lend themselves to repair by this method Vascular suture is also an essential part of the operations for vessel grafting for embolectomy and aneurysmorrhaphy

A great variety of suture material has been employed, but at the present time most surgeons rely on fine black silk fitted to eyeless needles, this is now supplied ready sterilized in tubes of liquid paraffin In an emergency, and when the special vascular silk is not available, very fine horse hair or even the thinnest of chromicized catgut may be used But whatever the material it should always be soaked in liquid paraffin or drawn through vaseline It is well to have sutures threaded both on straight and curved needles Fine-toothed dissecting forceps vessel clamps with spring or rubber-covered blades, fine sharp scissors and a fine, thin-bladed, very sharp scalpel

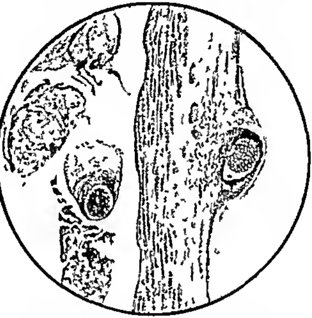

Fig 279 —Fine silk suture suspended in lumen of abdominal aorta of dog

On examination 25 days later a firm intima like lining covered the suture (After Hamilton Drummond and Shaw Dunn)

for trimming the vessel ends should also be ready The straight needles are usually manipulated with the fingers, but the small curved needles require a fine needle holder, such as may be used for cleft palate work or nerve suture It should be of a pattern with which the surgeon is thoroughly familiar A pair of fine artery forceps serves the purpose quite well The whole field must be kept moist with isotonic (3 8 per cent) sodium citrate solution Some authorities think it essential to prevent the suture material coming in contact with the circulating blood but experimental work and the scrutiny of healed anastomoses has shown that suture material abutting on the vessel lumen, whether paraffin coated or not, does become clothed with an intima like covering which makes the internal surface of the suture line perfectly smooth and even (Fig 279)

Arterial clamps should have non-serrated blades of the bow type

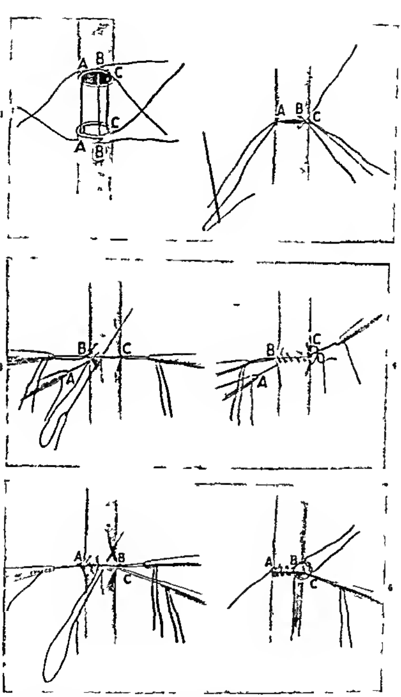

Fig 280 —Arterial suture by Carrel's method

1 Three equidistant stay-sutures in position. 2. Making vessel triangular to aid suture 3 and 4 Suture of second side of triangle with vessel partially rotated. 5 and 6. First side of triangle being sutured with continuous suture through all coats of vessel. (*See also* Fig 281)

and with a sufficient degree of "spring" But clamps are not easy to apply in deep wounds and a fine rubber tube passed under the vessel and gently drawn towards the surface will often suffice For larger vessels it may be necessary to cross the ends of the rubber tube in front of the vessel and to fix them temporarily with an artery forceps, or by ligature

Technique —These operations have often been carried out under local infiltration anæsthesia but, unless there is some special feature, general inhalation anæsthesia is not contra indicated The limb should be exsanguinated and a tourniquet applied, it is then placed in a suitable position so that the surgeon can work comfortably and unimpeded The incision should be so planned as to give the most direct exposure, and of such length that the use of retractors is reduced to a minimum It follows that whenever possible it should be placed over the line of the artery and it will usually be several inches long, depending on the depth of the artery and on the muscular development of the part Of course it does not follow that the length of artery exposed will be of great extent, but the easy access to the two inches or more required will depend upon the free incision of the superimposed parts The vessel is carefully isolated, the greatest care being taken to reduce handling to the minimum It must be raised from its sheath sufficiently to allow arterial clamps or rubber slings to be applied above and below the site of proposed suture It assists the separation of the vessel from its sheath if the cellular bed in which it lies is distended with normal saline Only blunt dissection is required, and the actual lifting of the vessel is done by slings or by fine mouse tooth forceps taking hold of the edges of the wound, which in any event will be trimmed Great care must be taken to preserve all branches Vascular clamps must include the whole width of the vessel in their grasp and they must be very lightly and gently applied When they are securely in position, the tourniquet may be removed Longitudinal and oblique wounds may be closed by a continuous suture Slight narrowing of the lumen is not necessarily a bar to success, though pronounced narrowing encourages thrombosis In transverse wounds involving more than one third of the circumference the vessel should be divided and restored by end to end suture

Of all the methods introduced for end to-end anastomosis of artery or vein, Carrel s classical suture still holds the field The chief points are (1) The application of three stay-sutures making the vessel at points of proposed union into an equilateral triangle (Fig 280, *1*, *2*) (2) Each side of the triangle is then secured by a continuous suture with a tie at each stay-suture (Fig 280, *3*, *4*) (3) All sutures pass through all coats of the vessel wall including the intima, which is everted The actual method of application of these sutures is best seen from Fig 280, *5*, *6*, and Fig 281 In the opinion of some surgeons two stay-sutures are sufficient

Needless to say, great care should be taken to avoid damage to the

vessel, and this refers not only to the ends, but also to the portion over which clamps are applied during the time of suture

In end-to-end suture the most essential part of the operation, whatever method be adopted is the complete removal of the adventitia from the vessel ends If this structure is left *in situ*, the vessel ends remain ragged, and while the continuous suture is being inserted a portion of the torn adventitia is likely to be caught and dragged into the lumen of the vessel, inevitably leading to clotting (Fig 282)

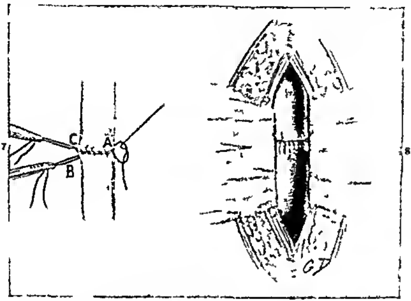

Fig 281 —Arterial suture by Carrel's method

7 Third side of triangle vessel completely turned rotation of vessel is reversed to bring this side of triangle into view 8. Suture of artery completed.

The best method is to pull the adventitia gently over the open lumen of the artery (Fig 283), and then to cut it off flush with the edge of the vessel with fine scissors The adventitia, when pulled upon, is easily stretched, and, when cut across, retracts well above the divided end of the vessel (Fig 284)

The artery should be well washed with the citrate solution to remove all blood Burnheim advocated the application of liquid vaseline or paraffin to the vessel ends to prevent clotting It is of the greatest importance to keep the structures moist and warm during the process of suture and this is done by dropping citrate solution, at a temperature of 100° F, over the wound throughout the operation After the suture is complete, the *distal* clamp should always be loosened first, allowing blood to flow through the anastomosis from below, and therefore at a much lower pressure than if the proximal clamp were removed In consequence the surgeon is better able to deal with any leak that may occur in the suture line If the leak be of any size the distal clamp should be immediately re applied, and a single suture put through all

the coats at this point. Light finger-tip pressure over the vessel after the removal of the distal clamp will allow the necessary clotting to occur at the stay-holes, where there is nearly always a leak when first the clamps are removed.

When the suture line seems reasonably well sealed the next step is the removal of the proximal clamp; this should be done slowly, while at the same time gentle pressure of a warm moist gauze should be applied at the line of suture. It is important not to apply pressure too forcibly nor for too long a time, for fear of inducing clotting at the

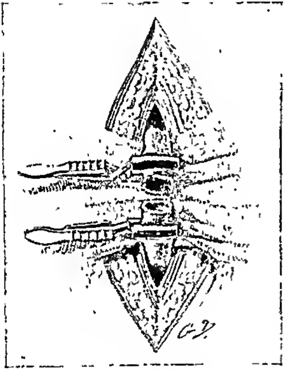

Fig. 282.—Arterial suture.
Cut ends of artery showing protruding adventitial coat.

Fig. 283.—Arterial suture.
Shows method of drawing adventitia over cut end of artery preliminary to removal.

site of anastomosis. The gauze is cautiously lifted and the anastomosis inspected. If there is no marked leakage and the pulsation passes normally to the distal segment, probably all will be well. But there is undoubtedly a considerable risk of thrombosis at the site of anastomosis and at the present time heparin solution is generally used in the hope of preventing this. Before either clamp is removed, heparin is injected into the segment of artery between them. This can be done by inserting a fine hypodermic needle into the intact vessel. After removal of the distal clamp has shown that the anastomosis is sound, more heparin solution is injected and the proximal clamp released. But if heparin is essential the logical method is to inject it into the circulating blood for some days after the vessel suture. [illegible]

should be remembered that many successful cases of vessel suture were reported before the introduction of heparin

Shelton Horsley* describes another method in which he applies three stay sutures followed by a mattress suture introduced by two needles he thus raises a flange round the divided ends of the vessel and the cut edges are left uncovered by the sutures (Fig 285) The advantage he claims for this method is that the intima is thereby more nearly approximated and that there is a minimum amount of suture material exposed in the lumen of the vessel A similar plan but using only one needle is recommended by Learmouth (1940)

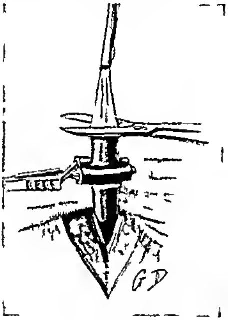

Fig 284 Arterial suture
Removal with fine scissors of protruding adventitia

Fig 285 —Shelton Horsley s flange method of arterial suture

Completely divided vessels may be difficult to repair by end to-end suture as they stretch to a very limited extent and are often anchored by branches which it may be unwise to divide

Lateral or small transverse wounds in arteries that are clean cut are the most perfect injuries to suture and give uniformly good results in the absence of infection Such injuries most commonly caused by sharp knives as in stab-wounds or by flying glass are dealt with by the application of proximal and distal clamps and suture The adventitia is removed and the vessel having been washed clean with warm citrate solution the rent is repaired by one continuous vaselined suture which passes through all the coats of the vessel

A small hole in a large vessel caused by the division or evulsion of a lateral branch may be closed in the same manner Persistent oozing may be arrested by placing a small piece of fresh muscle over the area

* Surg Gyn Obstet May 1914 x d 536

of repair and pressing it into position for a minute or two with the tip of the gloved finger

Suture of wounded blood-vessels.—The experiences of the war of 1914–18 proved that primary vascular suture for gunshot wounds was highly unsatisfactory. This was due (1) to the great extent of damage done to the vessel walls by the impact of the missile (2) to the infection of the operative field (3) to the lack of time and, often, of suitable environment. In wounds with extensive damage to the surrounding parts sepsis was almost certain to follow, and gas gangrene was frequent when the tissues around the sutured vessel were closed without adequate drainage, for it is well known that gas gangrene is exceedingly probable in the presence of devascularization of muscle. In injuries to main arterial trunks in the upper limb, ligature of the bleeding vessel is often all that is necessary provided no great damage to the collateral circulation has occurred and this should be remembered when arterial suture is under consideration. Similar conditions may obtain in civil life especially with railway or severe motor accidents. Practically any of the main limb vessels may be ligatured in continuity without risk of gangrene, but it is otherwise in severe injury to the soft parts which may have seriously damaged the smaller vessels on which the collateral circulation depends. In the hope of saving such a damaged limb the surgeon may be justified in trying primary arterial suture. It is essential to do everything possible to prevent sepsis and in these circumstances the intelligent use of chemo therapy is valuable.

Transplantation of Segments of Blood-vessels

It was long ago demonstrated by Carrel* that segments of blood-vessels may be successfully transplanted from one animal to another of the same species. Further it has been shown by numerous experimentalists that rubber tubes and cannulæ can be introduced between the ends of divided arteries in animals with varying but, on the whole, successful results. Guthrie transplanted a portion of the vena cava of a dog, preserved in 2·5 per cent formalin for sixty days, between the divided ends of the common carotid artery of another dog. At the end of twenty-three days the vessel was laid open, and the lumen of the transplanted segment was found to be patent and capable of carrying on the circulation; there was slight thickening, but otherwise the graft looked normal. This clearly proves that a preserved venous graft may adequately serve the mechanical function of an artery over a period of more than three weeks. The bridging of an arterial defect by the transplantation of segments of blood-vessels has now become more than an experimental procedure, and venous grafting has been performed many times with success. It is obvious that a fresh graft is the best, and that it should be supplied from the patient's own vessels. A venous graft is employed, as its removal does no damage to the circulation; the internal saphenous vein will be found useful

* *Journ. Amer. Med. Assoc.*, 1907, ix, 226

for the purpose The graft should be placed in the reverse position so that any valves present will not impede the circulating blood Such grafts have been used after excision of aneurysms to bridge a gap between vessel ends which could not be approximated for direct suture They have also been employed in wounds of large vessels and in involvement of large arteries in resection for malignant disease

Hogarth Pringle of Glasgow * records two cases of aneurysm treated by this method after resection of the sac In one case (left popliteal aneurysm) he was unable to join the cut ends of the artery so he employed 4 in of the internal saphenous vein from the opposite thigh as a graft and by this means using Carrel s method of suture he restored the circulation *Three months later the patient returned to* work and when seen again nine months after the operation there was pulsation in the popliteal graft which could be seen and felt and both pulses at the ankle-joint were of the same volume This man worked regularly until he died from heart disease three years and three months after the operation He always declared that the operated limb was as good as its fellow The grafted area examined after death showed a patent lumen of rather larger diameter than the adjacent artery The other case was that of a blacksmith who sustained an injury to the brachial artery just above the elbow joint At operation five weeks later the artery was found to be split longitudinally for an inch This portion was excised and a graft from the internal saphenous vein implanted The result was successful and the patient returned to work in fourteen weeks with the circulation through the injured artery restored—for pressure over the grafted area immediately arrested the radial pulse This man also declared that the operated limb was as good as its fellow A year afterwards he joined the army and served in Gallipoli where he was killed in action

The same procedure was carried out by Lexer† after excision of an axillary aneurysm and the result was also successful

In 1912 Boothby‡ pointed out certain difficulties in performing this operation on account of the thinness of the venous segment His description of an operation performed on an animal may be thus summarized —

After the vein (vena cava for example) is freed for a distance of 2 in *ligatures are applied at the upper and lower ends Close to the* upper ligature the vein is grasped by a pair of smooth forceps and a small nick is made in its wall Then a stay suture is passed through the vein emerging at this nick the second stay is placed on the side of the vein wall towards the back in the same way also emerging through this nick the third is placed on the opposite side to the first and likewise emerges through the same hole In like manner three stay sutures are placed at the other end of the segment Each stay as soon as placed is clamped by a mosquito forceps to keep it in place and prevent its needle from falling off When all the stays are placed

* *Lancet* June 8 1913 i 1795
† *Arch f klin Chir* 1907 lxxxiii 459
‡ *Ann Surg* September 1912 lvi, 409

the division of the vein is completed, and it is transferred to the place prepared for it in the artery (aorta, for example) Each stay is rapidly passed, in its appropriate position, through the wall of the aorta from within out, and tied to complete the junction The circular suture is then proceeded with

Conclusions —When possible, the segment to be transplanted should be taken from the patient's own vessels

Transplants in nearly all cases should be venous and not arterial as few arteries of suitable size can be spared As a rule, the internal saphenous vein is the most convenient vessel

Care should be taken in selecting a portion of vein for transplantation, to avoid a segment with branches Should it contain valves, they must face the proper way

The transplanted vein quickly becomes hypertrophied and capable of withstanding the arterial pressure

Though opportunities for arterial suture are infrequent at least in civil life, it is a good plan to have the special instruments and sutures always ready, kept together in a box or case for the purpose Suitable needles, threaded with black silk ready sterilized and in sealed glass containers can be purchased

Artificial Canalization—Tuffier's Method

This is an ingenious method suggested by Tuffier for dealing with cases where the wound of the vessel is so extensive as to make suture impossible, it consists in the introduction of a silver or glass cannula between the divided ends of the torn vessel It is employed especially in cases of injury of large vessels, such as the carotid, the femoral,

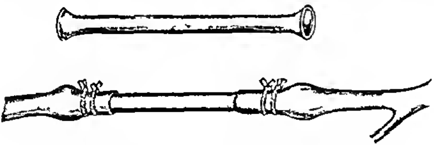

Fig 286 —The glass cannula as used by Gordon Murray and Janes (*Brit Med Journ* July 6th 1940)

or the popliteal arteries, where primary ligature may lead to gangrene before the establishment of a satisfactory collateral circulation

The cannulæ are made with a flange at each end, and in various sizes suitable to the calibre of the artery (Fig 286) The tubes used to be prepared by immersion in a solution of paraffin wax and vaseline, but since the use of heparin this is probably unnecessary

The torn vessel is temporarily occluded with Crile's clamps and its lumen washed free of blood, the damaged ends are trimmed up, the

additional advantage of interrupting the vaso constrictor pathways which may be so much stimulated by simple ligature as to set up peripheral spasm in the arteries, thus interfering with the development of the collateral circulation By allowing the ends to retract it also does away with longitudinal tension and makes occlusion easier and more secure and even in the presence of sepsis this method is considered safer than any other Every effort should be made to have the ends buried in the soft tissues and, when this does not occur naturally as the result of retraction neighbouring muscles should be drawn over them When it is necessary to ligature a branch near a main trunk it is most important to leave as long a stump as possible, and especial care should be taken to cover the ligatured vessel with muscle or other tissue such as fascia or a neighbouring salivary or other gland

3 Treatment of the vein Formerly it was emphasized that the greatest care should be taken to avoid injury to the vein, but it is now recognized that it is safer to ligature the vein at the same time as the artery By this means there is less likelihood of gangrene Some doubt has recently been expressed about the truth of these statements, but I am convinced of their general accuracy Even if ligature of the vein only plays a minor part in securing better nourishment of the limb it can at least be urged that this step never does harm

The principles of the operation are as follows —

(1) The incision should be made in such a way as to secure the most direct exposure of the artery and with as little retraction and manipulation as possible

(2) The guide to the artery is its known anatomical course, and at each step the definition and recognition of structures which have the most direct relationship to it Each vessel has some landmark which ought to be known and which is recognized as the 'rallying point' for that particular vessel It is essential that the incision should be of sufficient length, the most frequent difficulties are due to inadequate exposure These operations are easier in the living than in the cadaver, for the pulsation of the artery is an excellent guide

(3) The vessel must be isolated from surrounding structures When the artery is exposed it should be very gently taken hold of with a pair of reliable artery forceps With these it may be drawn towards the surface so that it may be safely cleared from surrounding structures This traction on the artery is the greatest possible aid and, if gently carried out, can do no harm Great care must, however, be taken in dealing with an artery that is obviously in an advanced state of atheroma, for such vessels have been known to tear across

(4) The ligature must be passed from the most important structure For this purpose an aneurysm needle is very useful, and whether this is passed threaded or unthreaded depends on the accessibility of the situation If, as recommended, the artery is to be divided between ligatures, the proximal ligature should be tied first After both are secured the vessel is held up and cut across where the traction forceps have been applied

(5) The vein should be tied separately some prefer to use silk for ligaturing veins it certainly has a better bite and a very fine size can be used

(6) The wound should be carefully closed muscle and fascia being drawn together so that the vessel ends are not in direct line with the skin wound in most situations this naturally follows It is better to avoid drainage whenever possible

(7) After the operation the part should be kept at rest in the most comfortable position and if there is any question of gangrene the greatest care should be taken to keep it at room temperature The limbs should have been previously cleansed dried and dusted with an antiseptic powder and should be loosely wrapped in wool

Aluminium Bands for the Occlusion of Large Arteries

This method was devised by Professor Halsted of Baltimore in 1906 it has since been modified and simplified by Matas and Allen It was introduced for the temporary or trial occlusion of large vessels but it can be used instead of the ordinary ligature The bands are made of aluminium and are perfectly smooth and with rounded edges They are 6 in long and of varying widths from $\frac{1}{16}$ inch and of such thickness that the band can be bent and comptessed round the artery by the fingers The vessel is exposed in the ordinary way as if for ligature and the band fashioned like an aneurysm needle, is passed around it and then gently compressed about the artery with the fingers until the pulse on the distal side becomes imperceptible The excess is then cut away with stout scissors Any desired degree of occlusion can be secured and the band may be left *in situ* or subsequently removed if it is desired to re-establish the circulation

The value of the method can best be illustrated by its use in a case of subclavian aneurysm described as follows by Homans (1939) If this (the band) is tightened just sufficiently to stop all pulsation in the aneurysm the state of the circulation in the arm will become clear in the following day or two In the event that the arm and hand remain reasonably warm and pink nothing more for the moment need be done but the state of the sac will of course be watched If it becomes smaller harder and remains without pulsation the aneurysm may be considered cured If the response is unfavourable that is if the hand and arm become white and cold threatening gangrene the closed wound should be re-opened and the band which has injured neither intima nor media should be loosened just sufficiently to restore the circulation

Simultaneous Ligature of Arterial and Venous Trunks

This question has engaged the interest of surgeons ever since it was brought prominently before the profession at the time of the 1914 1918 War If for instance the main artery of a limb has been wounded and ligature is necessary what should be the treatment of the main vein whether injured or not? Information gathered from experi

ments upon animals led to the conclusion that when a main artery requires ligature the accompanying main vein should also be tied (Fig 287)

It has been a surgical axiom from the time John Hunter advocated proximal ligature in 1785 that great care should be taken to avoid all injury to the vein when it is found necessary to ligature the main artery But Makins in his Bradshaw Lecture * pointed out that proximal ligature of the femoral artery in cases of arterio venous aneurysm was followed in a large proportion of cases by gangrene of the limb while consistently good results were obtained by excision of

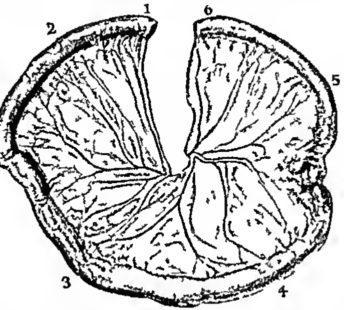

Fig 287 —Simultaneous ligature of artery and vein (experimental) Portion of small intestine of cat

The segment between 2 and 3 was treated by ligature of both arteries and veins On examination forty eight hours later this portion showed no change The portion between 4 and 5 was treated by ligature of the arteries without the veins a patch of gangrene 1 in in length occurred The vessels between 3 and 4 were not touched (Hamilton Drummond)

the implicated segment of both artery and vein This classical observation led him to suggest that when it became necessary to ligature a main arterial trunk its accompanying vein should also be tied and this course was adopted in France during the war from the middle of 1917 onwards His explanation of these results is as follows —

The main vessel being occluded and the direct arterial pressure from behind being abolished blood which has been carried by the arterial collaterals to the distal portion of the injured trunk instead of passing to the peripheral circulation takes the course of least resistance into the vein through the arterio venous communication and thus the limb practically bleeds to death much in the same way as though the distal end of the wounded artery opened on the surface Hence the comparative safety of removal of the communication *en masse* and

* *Lancet* 1913 ii, 1713

occlusion of all four openings by ligature, which has been confirmed by numerous operations during the present war"

Experience during the intervening years has left the matter in some doubt None the less it may be stated with confidence that, if it is necessary to ligature the main vein at the same time as the artery, this may be done without increasing the risk of gangrene I would go further, and advise that if there has been extensive damage to the soft parts likely to interfere with the development of the collateral circulation, simultaneous ligature of the vein would be an advantage Of course this step cannot ensure the avoidance of gangrene

Ligature of Special Vessels

The analysis of cases by Prof William Sheen* and the observations of the late Sir Charles Ballance† lead to the conclusion that there are certain cases of aneurysm of the innominate artery which are suitable for proximal ligature and that this is to be preferred to distal ligature, which may produce a diverticulum of the aorta and so increase the pressure within it To guard against recurrence Sheen recommends simultaneous ligature of the common carotid The type of aneurysm suitable for proximal ligature is one that arises at the bifurcation of the innominate artery

Ballance held that a portion of the sternum should be removed when performing this operation, and pointed out that, from an anatomical point of view, the ligation of the innominate artery is a cervical operation which should not present any great difficulty Sheen recommends a vertical incision from the cricoid down over the sternal notch and does not consider it necessary to divide or remove bone

Several methods of bone removal are suggested—either division of a portion of the manubrium with the inner end of the clavicle, or longitudinal division of a portion of the manubrium, allowing the sternum to be divided laterally and replaced again after the operation Sir William Wheeler recommends that the inner end of the clavicle and the upper part of the right half of the manubrium sterni should be divided and turned up with the sterno mastoid being replaced at the conclusion of the operation (Fig 288) These methods convert an almost impossible feat into a workmanlike undertaking I have several times removed the inner third of the clavicle and a portion of the manubrium sterni when exposing the upper œsophagus It is not necessary to replace the bone, the subsequent movement of the arm being excellent

The subclavian artery is easily tied in its third part This operation may be required as a preliminary to interscapulo thoracic amputation The classical route is very satisfactory if attention is paid to all the details, i e the shoulders must be elevated on a hard cushion or sandbag and the arm must be well pulled down by the side The incision should be the whole length of the clavicle All superficial veins must be caught and divided The outer border of the sterno-mastoid and the scalene tubercle on the first rib are the important guides

* *Annals of Surgery* 1905 xli, 1 † *Brit Journ Surg* Jan., 19— ix 43—

Exposure of the first and second parts is admittedly difficult, but the difficulties largely disappear with a wide exposure. The skin incision must extend from the inner border of the sterno mastoid right across the base of the neck as far as the anterior border of the trapezius muscle on the same side. If at any stage further room should be required another incision may be made along the anterior border of the sterno-mastoid and carried down over the upper part of the sternum. The sterno mastoid muscle is completely divided just above the clavicle and the inner third of that bone is removed by separating the structures close to the bone, taking care to make the separation

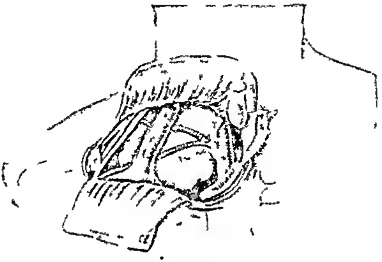

Fig 288.—Exposure of the innominate artery by section of the clavicle and manubrium sterni

(Drawing lent by Sir W. Wheeler.)

subperiosteal on its deep aspect. The bone is cut across with any convenient type of small saw, the final stages being completed with bone forceps. With the fragment held in strong forceps its inner end is disarticulated; the claviculo-sternal joint is very strong and it facilitates matters to detach the meniscus at the upper border of the articular surface of the clavicle. At the inner border of the wound the sterno hyoid and the sterno thyroid muscles may be divided. With blunt gauze dissection the parts can be well exposed on the left side. A sharp look-out must be kept for the thoracic duct, which can always be easily identified as thin walled, beaded, pale and without pulsation. If injured it should be ligatured and divided. The jugular and subclavian veins can be readily exposed and gently thrust aside. It may be a great help to double-ligature and divide the internal jugular, great care being taken to leave sufficient of the vein beyond the ligatures. It must be remembered that the apex of the pleura extends up into the neck behind the subclavian and the artery must be very gently

separated from it After ligature of the artery or its branches as may be required the wound is closed If the divided sterno-mastoid can easily be approximated to muscle remnants on the sternum or to the ends of the infra hyoid muscles so much the better, but this is not essential It is sufficient carefully to suture the skin with the deep fascia and platysma For some days the arm is kept supported on a pillow or by the side The functional recovery is quite remarkable A posterior approach to the first part of the left subclavian has been described by A K Henry (Exposures of Long Bones and Other Surgical Methods) and has every appearance of being satisfactory

Ligature of the common carotid artery.—The risk of cerebral symptoms sometimes fatal is a real danger They rarely occur in patients under 25 years of age Le Fort's statistics show 45 per cent of cases in which brain symptoms followed operation, but this is in excess of the experience of most surgeons Leonard Freedman* considers that unfavourable results, such as hemiplegia and symptoms of cerebral anæmia are caused by thrombosis followed by embolism rather than by anæmia from failure of the collateral circulation, a theory to which Perthes† subscribes, and in favour of which he advances the following reasons (1) The almost invariable interval between the time of the operation and the cerebral symptoms (2) The suddenness of the onset of symptoms, resembling an apoplectic stroke (3) Post-mortem examinations have repeatedly demonstrated thrombosis and emboli (4) Temporary ligature of the vessel, or the gradual diminution of its calibre by metal bands unaccompanied by symptoms, does not prevent serious brain mischief after permanent ligature (5) Cerebral complications occur more frequently after ligation of the common than of the internal carotid artery, because the return flow from the external carotid may detach emboli from an extending thrombosis in the main arterial trunk Perthes has shown that after the release of a temporary ligature, with re-establishment of the circulation cerebral symptoms may occur In 1941 this question is still under discussion Schorstein‡ contends that previous impairment of cerebral circulation is the crux of the matter, but the fact remains that such symptoms may arise after ligature in not very elderly and apparently healthy subjects The practical point seems to be that ligature of the common carotid should be avoided when ligature or excision of the external carotid will suffice When the operation is essential it may be some help to ligature the internal jugular vein at the same time and, since there is no evidence that this step is harmful, there is no reason against it To avoid the occasional alarming effects of ligature it has been suggested (Holman, 1937) that a trial ligature might be carried out under local anæsthesia, the effect being observed for an hour A possible solution to the problem may be provided by gradual obliteration of the vessel, but this would mean multiple interventions When distressing condi-

* *Ann. Surg* September 1 1921 lxxi 316.
† *Arch. f klin. Chir* Bd. September 1920 cx v 403.
‡ *Brit Journ Surg* 1940, xxvii, 50

tions like intra-cranial aneurysm demand ligature if life is to be made bearable, the risk must be taken

Technique —The vessel is most conveniently ligatured just above the omo hyoid An ample incision in the line of the artery is necessary The first guide is the anterior edge of the sterno mastoid in muscular subjects this completely covers the artery and must be well retracted The carotid sheath is freely opened and the vein will be found overlying the artery It must be carefully isolated for some distance so that it can be drawn outwards without risk of being torn The vagus nerve lies posteriorly between the artery and vein it must be exposed that it may be avoided There will be no difficulty in isolating the artery for the purpose of passing the ligature if it is gently drawn towards the surface the surrounding structures being thrust aside by blunt dissection

External carotid.—An ample incision along the anterior border of the sterno mastoid is essential It should commence opposite the angle of the jaw and extend to the lower border of the thyroid cartilage The artery is much higher in the neck than is usually supposed It is easy to mistake the internal for the external carotid and the true guide is the presence of branches on the latter The vessel is often obscured by the common facial vein which may be very large It should either be drawn gently downwards and forwards, or divided between ligatures The carotid is to be sought between the anterior border of the sterno mastoid and the posterior belly of the digastric muscle The hypoglossal nerve is usually seen crossing the field just a little below the latter muscle

The lingual artery is nowadays seldom tied as a preliminary to operations on the tongue The classical exposure through a small incision may be very difficult The best plan is to make a large curved incision such as is used for excision of the glands in the submaxillary region With this exposure, the anatomical landmarks are easily identified

The thyroid vessels are sometimes tied to influence acute thyroid intoxication but it is generally conceded that it is as safe, and scarcely more difficult, to perform partial thyroidectomy If necessary, the superior vessels can be caught and tied in a bunch just as they enter the upper pole of the lateral lobe It is to be remembered that the position of the latter varies with the degree of enlargement of the gland

Ligature of these vessels is described in the section on the Thyroid Gland, Vol II

The axillary artery can be exposed in the greater part of its length by an incision in the axilla along the course of the vessel With the arm held at right angles to the body and careful retraction, this presents no difficulty Ligature of the third part of the subclavian can usually take the place of ligature of the first part of the axillary and is much easier and more satisfactory When the tissues are disturbed and displaced, as they may be in traumatic aneurysm there need be no

hesitation in making an incision directly over the line of the artery from the middle of the axilla to the centre of the clavicle Both the pectoral muscles can be divided in this line and if necessary the clavicle With the arm drawn away from the side and the shoulder allowed to fall back the exposure is very free Afterwards the ends of the clavicle should be drilled and fixed together with strong catgut or wire and the muscles carefully repaired with stout catgut

The common and internal iliac arteries should always be approached by the intra abdominal route Good anæsthesia and the high Trendelenburg position greatly facilitate the operation A median incision is best and should extend from just above the umbilicus to the pubes The peritoneum over the artery must be picked up before being incised and there should be no hesitation in dividing it for 2 or 3 in The ureter tends to adhere to the peritoneum but it can always be identified by its position and the fact that it vermiculates at intervals and when touched The vein must be carefully separated from the artery before passing the ligature When it is decided at what point the artery is to be tied it can be held by forceps and gently drawn inwards the vein being carefully thrust aside by gauze stripping It is not easy to tie the internal iliac artery and great care must be exercised for it hugs the pelvic wall and is intimately connected with the vein

The external iliac can also be tied by the intraperitoneal route but in most cases this is not necessary It can be reached conveniently by making the classical oblique incision in the iliac fossa ½ in above Poupart s ligament This incision must stop short of the internal abdominal ring on the one hand and the deep circumflex iliac artery on the other After incising the muscles and the transversalis fascia the peritoneum can be easily stripped up and the artery reached extraperitoneally The lowest part of the vessel can also be exposed by an oblique incision just below Poupart s ligament The common femoral is identified and with the thigh slightly flexed the inguinal ligament can be drawn upwards with a strong narrow retractor when the vessel can be exposed and tied

The femoral artery and its branches present no special difficulty provided adequate incisions—six or more inches in length—are employed When the intervention is for primary hæmorrhage it is imperative to expose the bleeding point which is often at the site of the origin of a branch In all circumstances both ends of the injured vessel must be secured Gunshot wounds in these areas are specially dangerous and there is great risk of subsequent gangrene The question of artificial canalization should be borne in mind (*see* p 497) In the upper three quarters of the thigh the incisions should be on the anterior aspect in the line of the vessels In the lower quarter the incision should be medial along the line of the adductor tendon The sartorius is exposed freed and retracted laterally or medially whichever is the more convenient The roof of Hunter s canal is freely opened and if necessary the vessel is traced down beyond the adductor into the upper part of the popliteal space

The **popliteal** vessels are best exposed by a long, slightly oblique incision extending from a hands-breadth above the centre of the popliteal space, slightly on the inner side, to a hands breadth below that point in the middle line

The **gluteal and sciatic** vessels —In dealing with wounds or small aneurysms or doubtful lumps which require exploration, direct incision over the buttock may suffice When there is great vascularity, as in large aneurysms or new growths, the hæmorrhage following direct incision may be appalling, and no incision should be made until a temporary ligature has been placed on the common iliac artery by the transperitoneal route The abdomen having been temporarily closed, the patient is then turned over so that the region of the lesion on the buttock may be explored This is best done by a very free incision along "Lizar s upper line ' which runs from the posterior superior iliac spine to the tip of the great trochanter In muscular subjects the skin incision may well be of this length The gluteus maximus is divided in the same line, which corresponds with the direction of its fibres As soon as its substance has been traversed, the cellular plane between it and the deeper muscles will be apparent By blunt dissection and good retraction, the pyriformis will readily be exposed, with the gluteal vessels in the region of its upper border and the sciatic below To secure a sufficient exposure it may be necessary to detach some part of the origin of the gluteus maximus from the crest of the ilium and the great sacro-sciatic ligament After the lesion has been dealt with and the vessels secured at the site, the wound must be packed while the temporary ligature is loosened. If, then, after removal of the packing, inspection shows that the hæmorrhage is completely arrested, the buttock wound may be closed, after which the patient is laid on his back and the laparotomy dealt with On the other hand, small persistent bleeding in the buttock may be traced to its source and dealt with by further direct ligature But if the bleeding cannot be arrested or if it is profuse, the temporary ligature must be again tightened while the internal iliac is secured by permanent ligature, after which the temporary ligature can be removed and the abdomen closed Attention must then be given to the toilet of the buttock wound These interventions are serious, much care must be taken to guard against infection, the necessary movements must be carried out slowly and deliberately, and time allowed for the patient to rest between stages Two operators may work together, one dealing with the abdomen and the other the buttock Of course, arrangements for blood transfusion must be in readiness

The **posterior tibial artery** presents features of special interest Most surgeons recognize the difficulty of dealing with hæmorrhage in wounds of this vessel These cases, when seen a few hours after injury, show a tense, brawny, painful swelling of the whole of the calf, often with free hæmorrhage from the entry or exit wound Immediate operation is demanded, not only to avoid further loss of blood but to lessen the risk of septic complication and gangrene

In the presence of much extravasated blood throughout the muscular planes of the back of the leg, it is often very difficult to find the bleeding-point. The usual incision for ligature of the vessel is made along the inner tibial border ½ in. behind the bone. After division of the skin, the deep fascia is incised and the inner edge of the gastrocnemius defined and drawn backwards. The soleus muscle is then divided about ½ in. from its attachment to the edge of the tibia and, when this is complete, the intermuscular septum or fascia covering the deep flexor muscles is exposed and followed up to the middle of the leg. The parts being then carefully retracted, the vessel is found lying on the tibialis posticus muscle. This is the ordinary textbook operation, but it will be found difficult and unsatisfactory in the cases under

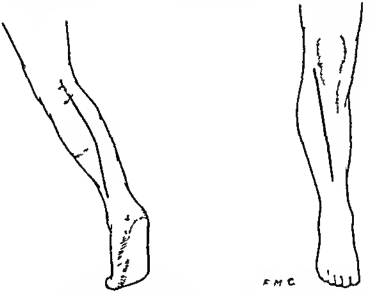

Fig. 289.—Lines of incision for ligature of anterior and posterior tibial arteries.

consideration. The best and most direct route (Guthrie's method) is by a long incision down the middle of the back of the calf, dividing the skin, the superficial and deep fascia, the gastrocnemius and the soleus; the incision should incline inwards, to end midway between the tendo Achillis and the internal malleolus (Fig. 289). With a finger as a guide, the two heads of the gastrocnemius can be separated, and the soleus divided vertically in the middle line. By retraction of the edges of the divided muscles the posterior tibial vessels will be exposed.

The advantages of this incision are directness of approach, better exposure in dealing with bleeding points, and more efficient drainage if necessary. Further, should the peroneal artery prove to be the source of hæmorrhage, and not the posterior tibial, the injured vessel is more easily found.

The upper third of the anterior tibial artery is difficult to expose on account of the upper part of the fibula. The incision should extend along the posterior border of the biceps tendon, around the neck of the

fibula and down over the anterior compartment of the leg The common peroneal nerve should be deliberately exposed over the length of the wound so that it can be drawn aside out of harm's way The outer head of the gastrocnemius and the soleus may be completely divided and, if necessary, a section of the upper third of the fibula excised, it is not necessary to replace the bone The anterior tibial in the upper third of the leg can readily be exposed if the incision employed is adequate (Fig 289)

Secondary Hæmorrhage

In cases of secondary hæmorrhage, which usually takes place between the seventh and tenth day after injury or operation as the result of wound sepsis, the patient does not pick up during the intervening days, but continues to look ill, is nervous and anxious and tends to lose weight

Treatment.—Palliative measures should always be avoided and, as soon as possible after the hæmorrhage, the wound should be explored and search made for the bleeding-point under a general anæsthetic and in a good light Very often this will be found to be the distal end of the vessel, but both ends must always be ligatured When the bleeding is from a branch near a main trunk the parent vessel should usually be ligated above and below the bleeding point The wound should be lightly sutured or left open and packed with gauze

Should hæmorrhage recur, a further attempt may be made to secure the bleeding point, but this may prove well nigh impossible In these circumstances the main vessel must be tied above in healthy tissue As a rule, the results are good, especially in upper-limb wounds, where the brachial and axillary arteries are concerned

Frequently, when secondary hæmorrhage occurs in compound fracture or large granulating wounds the actual source of the hæmorrhage cannot be determined, on account of inflammatory swelling Here the best results will be secured by packing strips of lint soaked in turpentine firmly into the wound All old clots and débris must first be removed with a sharp spoon Excess of turpentine must be squeezed out of the lint and some dry strips should be laid on the surface The surrounding skin should be protected from the blistering effects of the turpentine by vaseline gauze The strips should be left *in situ* until they loosen spontaneously, this occurs in four or five days, a curiously slimy discharge being thrown out The method is most effective, and septic wounds usually clear up well as a result It must be remembered that in some cases amputation may be a life-saving measure

Removal of Emboli from Arteries

Cardiac disease is the commonest source of a peripheral embolus Of recent years the diagnosis of embolic block has been followed increasingly by the operation of arteriotomy for removal of the embolus The Scandinavian surgeons have taken a great part in this development, and in 1936 Einar Key of Stockholm was able to state

that 882 embolectomies had been performed in Sweden with a very encouraging degree of success While in many cases gangrene may be averted it must be realized that the patients are often the victims of cardiac disease and that late deaths from that cause are not uncommon But patients have recovered and continued in good health for years even after multiple embolectomy French surgeons following the teaching of Leriche hold that the impaction of the embolus causes widespread peripheral vascular constriction and for that reason they maintain that arterectomy is the best way to deal with the condition In the upper limb the collateral circulation develops so satisfactorily that spontaneous recovery may usually be expected Antispasmodic drugs sometimes have a considerable effect But in elderly subjects gangrene may follow and if there are no definite signs of returning circulation in about 6 hours operation is indicated When the embolus lodges in the abdominal aorta or anywhere beyond gangrene nearly always follows and operation is imperative

Clinical features—It should be realized that the onset is nearly always sudden and that the main features are pain pallor cold with numbness and paresis and absence of arterial pulsation The affected limb looks and feels dead

Localization—Emboli usually lodge where vessels divide (Fig 290) but secondary thrombosis may spread from the original site Embolism may be repeated and there are many instances where a second embolus elsewhere has followed successful embolectomy It is important to endeavour to determine the site of lodgment before cutting down on the vessel the site of the initial pain is the surest indication On general principles this will be somewhat above the site of evident arrest of circulation and may be expected where the vessels divide The pulsation in the vessel ceases just below the impaction but the vessel may not be readily accessible for palpation or in any event the pulsation may be weakened by the poor general condition of the patient When the vessel is accessible the actual embolus may be felt and that area may be acutely tender

Fig 290—A typical riding embolus at the bifurcation of the carotid

(Reproduced by permission from D L Griffiths, *The Lancet* 1934 Dec 1)

Time for intervention—If an attempt is to be made to remove the embolus it should be as early as possible The chances of success are very good up to 6 hours but rapidly diminish afterwards and are very slender in 24 hours The interference must be looked upon and managed like an acute abdominal emergency

Technique.—Local or spinal anæsthesia should be employed and great care exercised in what may be an extensive dissection. The first indication is to expose the vessel, and for this purpose it is necessary to make a sufficiently long incision. The actual length will depend on the anatomical build of the individual and on the accuracy of the localization of the obstruction. When the vessel is exposed the site of the embolus may be perfectly obvious, or may be in some doubt. In the former case a definite bulging may be noticed in the vessel and there may be quite forcible pulsation which stops at this point. On the other hand, though pulsation may be feeble it may be readily felt up to the suspected area while being much less marked below. In these circumstances it is highly probable that the embolus is causing only partial blocking. When the site has been located the vessel must be isolated and means must be taken to control the circulation, either by clamps or by rubber slings. The latter are generally most convenient and are very efficient, but when the arterial wall is degenerated it is most important that they should not be pulled on at all forcibly or it may be torn through The next step is to open the vessel by an incision about ½ in long. This is better made at the lowest part of the embolus or even just below it. When the lumen of the vessel is opened it should be gently held apart with fine guide sutures; while the sling on the distal side is kept in position, the proximal sling is carefully released in the hope that the force of the current will drive out the embolus. If it does not do so, then the obstruction should be very gently milked down with the fingers towards the opening in the vessel. It is very much better to remove the embolus in this way than to introduce forceps, or any instrument which might damage the intima. When the obstruction has been cleared on the proximal side, the distal sling should be released in the hope that the return current may be unimpeded or may wash out any small portions of embolus that have been displaced from above or secondary thrombus that has formed beyond the embolus. It is not enough for the blood to well up; it should spout with the normal pulsations Of course, if the lumen of the vessel cannot be freed by external manipulation then forceps or, better still, a small scoop with a blunt end may be introduced into the vessel, not so much with the idea of scooping out the embolus as in the hope that it may be loosened and broken up so that it can be washed out by the blood stream. It is after the removal of the obstruction that heparin is most useful, applied locally to diminish the risk of any immediate re-clotting. At the same time the blood stream generally may be heparinized to diminish the risk of further emboli, either at the site or elsewhere (Gordon Murray, 1940). The vessel is closed with fine vascular silk.

In the after care it is necessary not to constrict the limb in any way. It should be comfortably laid on a pillow, slightly flexed, and should be under close observation. In most favourable circumstances the condition of normal vascularity returns immediately, but in some cases this may be delayed for several hours, and even in the most

successful cases there may be pain for two or three days Secondary embolus either in the periphery of the vessel operated upon or emboli in other vessels must be looked for Cases are on record where multiple interventions have been followed by success and there is no reason why the surgeon should be deterred especially since the introduction of heparin *

Mortality and after results—In the 382 Scandinavian cases 59 4 per cent died in hospital 22 5 per cent were completely cured, with restoration of the limbs and 18 1 per cent were cured after gangrene and amputation It is significant that of those operated upon within 10 hours 55 per cent regained normal circulation

Embolism of the abdominal aorta presents its own problems † The clinical picture of lower abdominal pain referred down the limbs and followed by sudden paraplegia is very striking Without operation the prognosis is almost hopeless Direct attack, at the site of impaction by transperitoneal or extraperitoneal exposure has proved too serious an intervention The best plan is to expose both femoral arteries just below Poupart's ligament On one side the vessel is surrounded by a rubber sling by which the artery can be temporarily occluded preventing the passage of a dislodged clot into the periphery On the opposite side (usually the left) the iliac artery is exposed by the oblique extraperitoneal incision of Abernethy With the fingers in the extra peritoneal tissues an attempt is made to milk down the embolus from the aorta into the femoral of the same side From this vessel it is removed by direct incision Endovascular manipulations with instruments should be avoided as much as possible After the main clot has been removed the opposite femoral should be examined and any clot which has been driven into its lumen must also be removed by direct incision Movement usually comes back to the limbs a few hours after operation but it may be 24 hours or more before full sensation returns and several days before pain completely disappears Occasionally ischæmic contracture has followed

Pulmonary Embolism

It was in 1908 that the German surgeon Trendelenburg described the first operation for this condition carried out on the human being In recent years there has been a great revival of interest in the operation largely due to the work of Gunnar Nystrom of Upsala In October, 1930, this surgeon published‡ no fewer than ten cases in which he had operated, five patients survived and of these two made a permanent recovery From time to time since that date other surgeons have recorded operations but recovery is very rare In 1939 Ivor Lewis published the first British success, being the twelfth in the world s literature § The cause of the condition is still a mystery, though it may be significant that it seldom occurs in patients under 30 years

* MacFarlane, *Br t Med Journ.*, June 1s 1940 1, 971
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Technique.—As a rule the patient is unconscious and the question of anæsthesia does not arise A vertical incision should be rapidly made just to the left of the sternum, over the costal cartilages, from the second to the fifth In a stout patient an additional horizontal incision along the third or fourth cartilages will be very helpful The fibres of the pectoral muscle are divided or separated and the second to the fourth cartilages rapidly cleared and excised This process is commenced near the sternum, and, with the finger or gauze, the cellular tissue is gently pushed outward in the hope of avoiding injury to the pleura The internal mammary artery may have to be ligatured The pericardium is thus exposed and should be caught between forceps just internal to the phrenic nerve, drawn into the wound and opened by an incision about 2 in long each edge being fixed by a stitch to the skin The pulmonary artery and aorta are identified, it is well to remember that the aorta has several times been opened in mistake for the pulmonary artery These great vessels are then surrounded by an elastic ligature passed with a special carrier after the model of Trendelenburg When this ligature is gently drawn upon it brings the vessels nearer the surface, steadies them and controls the circulation when required The pulmonary artery is opened by an incision about half an inch long If the embolus is at once found it may be removed by special forceps but *if it is not easy to reach* or is broken up, a suction apparatus may be required As soon as the clot is removed the elastic ligature is relaxed, in order to demonstrate that the pulmonary vessel is clear When this has been done, a special clamp is used for temporary closure of the incision in the artery The moment closure is complete, attention must be directed to the heart-beat If it does not return spontaneously, it must be stimulated mechanically, and if this fails 1 c c of a 1 7,000 solution of adrenaline should be injected into the root of the aorta

* Fresh warm cadavers should be employed whenever possible

Artificial respiration may also be required It is essential to realize that the major steps of the operation up to the closure of the pulmonary artery by the special clamp must be completed in *a few minutes* if the operation is to have a chance of success Once the heart has started to beat the operation may be completed in a more leisurely fashion The incision in the pulmonary artery is closed with a continuous suture of fine paraffined silk By this time the patient may have become conscious and may require some anæsthetic All vessels have to be carefully caught and tied The pericardium is closed completely by suture and the parietal structures are dealt with In many apparently successful cases death has occurred after some hours

In a characteristically careful paper * which should be studied by those who may be called upon to undertake this operation Arnold K Henry comments on the difficulties which he confronted in dealing with three cases He makes some very helpful suggestions and gives precise details of the steps he recommends Henry contends that the classical sound for passing the rubber tourniquet around the pulmonary artery is not a very satisfactory instrument and points out that the artery can be readily steadied and its circulation controlled between a finger passed into the sinus transversus and the thumb He also found that the forceps for removing the clot were clumsy and unwieldly and recommends a glass cannula with suction The incision he advocates is T shaped down the left border of the sternum for seven inches and along the second rib to the same extent Six inches of the cartilage and rib is removed The summary to his paper can be usefully reproduced here Flaps are reflected widely enough to reduce working depth by making a new surface at the level of the ribs The epigastrium is opened early for possible cardiac massage Wide resection of the 2nd left rib gives oblique access to the pulmonary trunk for through the large gap the lung apex can be mobilized and flattened backwards within its pleural sac These parts are seen best when a pillow is put under the left scapula of the patient The likeness of the pericardial wall to thin dura helps the surgeon to find it through any thickness of prepericardial fat Two methods of finding the transverse sinus are described No sound or tourniquet is passed through it the sinus is used merely in locating and steadying the pulmonary trunk The aorta is left undisturbed The pulmonary trunk is separately controlled with the fingers it is not hooked up An aspirating cannula properly curved is used instead of forceps for removing clot The cannula requires only a short opening in the pulmonary trunk and when it enters the lumen hæmostasis can be secured at once The time during which fingers occlude the lumen of the trunk is thus reduced to the few seconds spent in making the opening and passing in the cannula Bleeding from the pulmonary trunk after the introduction of the cannula is prevented by crossing the two hæmostats which have caught the lips of the opening in its wall this is further sealed by pressing it against the cannula A tap

* Lancet Feb 4 1940 349

stops aspiration so that circulation may proceed while the cannula is redirected from branch to branch"

ANEURYSM

Arterio venous Aneurysm

In civil practice this condition is but rarely met with, whereas every great war is followed by a spate of aneurysms of this type The statistics gathered from the war of 1914-1918 were closely studied, and furnished such information about the incidence, features, natural history and management of the malady as will almost certainly be repeated in the conflict now raging (1941)

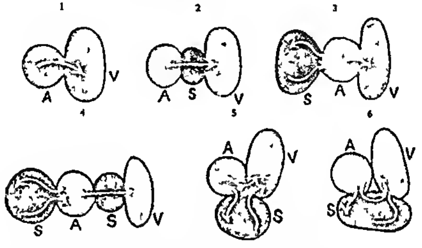

Fig 291 —Arterio venous aneurysms (*After Makins*)

1 Aneurysmal varix 2 Arterio venous aneurysm 3 Arterial aneurysm with aneurysmal varix 4 Arterial and arterio venous sac 5 Arterio-venous sac with common opening into artery and vein 6 Arterio-venous sac with separate openings into artery and vein

Makins (" Gunshot Injuries to Blood-vessels ") examined the records of 272 cases of traumatic aneurysm, the result of war wounds, admitted into the London hospitals, and found that 120 were arterial, 100 arterio-venous, and 52 aneurysmal varix

Matas, on the other hand, believes that aneurysmal varix is the most common arterio-venous lesion, the two vessels communicating by a direct fistulous opening He found that, as a rule, when an adventitious sac existed it was situated either in front of or behind the vessels rather than between With regard to the relation of the vessels to one another and to the adventitious sac (Fig 291), these authorities are in agreement

It is sometimes stated that the arterio-venous communications have a distinct tendency to contract, and that they may even close spontaneously Makins recorded a case of arterio-venous aneurysm of the innominate artery and vein which, after a period of five years, underwent a spontaneous cure This tendency to natural cure is also shown by animal experimentation, and, further, it occurs in cases where

arterio venous anastomoses have been carried out for senile gangrene In the well-established condition which usually comes before the surgeon natural cure is most unlikely and I have certainly never seen it The condition may be expected to get steadily worse and when large vessels are involved the heart gradually becomes decompensated and there may be tachycardia and dyspnœa on the slightest exertion Holman (1937 ⁹) has drawn special attention to this aspect In very early cases where there is hope of spontaneous cure the area may be supported by an elastic bandage while all exertion is avoided Surgical treatment will usually be necessary on account of (1) pain (2) buzzing noises as when the lesion is in the neck (3) obstruction to the peripheral venous circulation (4) increase in the local distension of the vein (5) disturbances of the eye in internal carotid and cavernous sinus cases (6) cerebral symptoms in carotid jugular communications (7) increase in size with aching and disability or (8) evidence of cardiac dilatation and embarrassment

Arterio-venous aneurysms occur most frequently in the carotid femoral popliteal axillary and tibial vessels

Treatment—Each case requires careful study and consideration By way of preparation a period of absolute rest in bed is essential and in bad cases two or three weeks will be required The great danger of hæmorrhage should be *fully* realized before any operation is undertaken and complete command of the arterial circulation is essential If an efficient tourniquet can be applied without encroaching on the operative field this will usually suffice but when there is great venous engorgement both a proximal and distal tourniquet should be employed In other circumstances the main supplying vessels must be deliberately exposed on either side of the aneurysm so that temporary ligatures can be applied

Where the aneurysm is large and the collateral circulation well developed the main trunk must be temporarily secured at a point above the origin of the principal collateral branches For instance in high femoral or inguinal aneurysm the common iliac must be controlled and this will require an abdominal approach In axillary aneurysm the third or even the first part of the subclavian will require temporary ligature

The operations available—Simple proximal ligature of the artery is never permissible for it is almost invariably followed by gangrene In these circumstances the blood which finds its way through the collateral vessels returns to the trunk *via* the communication in the vein so that the periphery is short-circuited and vascular starvation results

The following methods are recommended —

1 Reconstruction—endo-aneurysmorrhaphy
2 Quadruple ligature of artery and vein
3 Excision

Whichever operation is carried out it is incomplete unless the communication between the arterial and venous systems is eliminated. In all peripheral arterio-venous aneurysms of moderate size excision or quadruple ligature is efficient. When the great vessels near the trunk are involved the reconstruction method is most desirable, but in just these cases are the difficulties greatest, and the surgeon is often glad if he can safely terminate the operation by multiple ligatures or excision.

Endo aneurysmorrhaphy.—This method, which may be described as

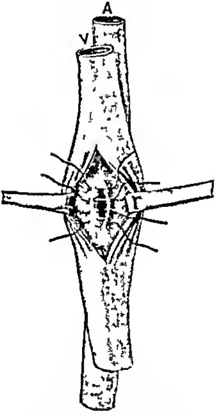

Fig. 292a.—Matas Bickham method of closing arterio-venous fistula. Incision in vein with separate sutures through fistulous opening

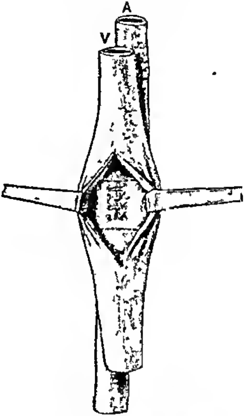

Fig. 292b.—Matas-Bickham method. Fistulous opening closed

the Matas-Bickham operation, dates back to 1904, and has since been more fully *described and strongly advocated by Matas* in *numerous* communications to the literature. One of his earlier papers* records his experience of 12 arterio venous injuries treated by it with a very large measure of success, and well indicates the scope of the measures he recommends. Of the cases, 1 involved the common carotid artery and internal jugular vein, 1 the external iliac vessels, 8 the common and superficial femoral vessels, 1 the peroneal, and 1 the subclavian

* *Surg., Gyn., Obst., May*, 1920, xxx, 456.

artery and vein These cases were all treated by opening the venous sac and suturing the orifice or orifices of communication In varicose aneurysm the approach to the opening was through the false sac, and in aneurysmal varix through the dilated vein (Fig 292)

This intravenous and intrasaccular suture is the ideal method of dealing with aneurysmal varix and arterio-venous aneurysms, as it preserves the circulation as far as possible It is undeniably a somewhat difficult operation and, as Rutherford Morison pointed out, scar formation may interfere with the exposure of the vessels necessary to control the circulation during the operation

In endo aneurysmorrhaphy for aneurysmal varix, the particular method by which the vein is to be treated can be determined only by the condition found at the operation The ideal plan is that which aims at the preservation of both vessels, more especially in the neck, but if the artery can only be sutured at the expense of the vein this should be done Part of the vein can then be used to reinforce the line of suture like a patch (Fig 293)

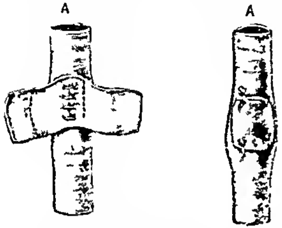

Fig 293 —Showing artery sutured and vein dissected off in Matas Bickham method leaving flap to cover fistulous opening

Matas describing the technique of closure of the arterio-venous fistula through the vein, lays stress on the importance of avoiding injury to the endothelial lining He employs warm saline to wash the fistulous opening clear of blood and sprays the wound with liquid vaseline to prevent coagulation while exploring the interior of the vein and he is careful to avoid sponging on account of the risk of damage to the intima In the future heparin may be expected to prove most helpful

Technique —The steps of the operation are (1) Exposure of both vessels by a long incision and their isolation above and below the communication (2) Occlusion of the vessels above and below with vascular clamps or rubber slings (3) Removal of the sac, by careful dissection in arterio-venous aneurysm, and in both vessels exposure of the aperture of communication (4) Repair of the holes in each vessel by suture

In carrying out this suture the needle is first passed through the fibrous tissue which binds the artery and vein together at one end of the fistulous opening and on the adventitial aspect of the vessels care being taken to avoid penetration of the intima of either vessel. The knot is tied so that it remains outside the lumen of both artery and

vein The suture is then passed obliquely from without through the vein wall close to one end of the opening, the extreme edges of which are brought together by a fine continuous suture passed through the intima and media until the other end of the opening is reached, when the suture is brought out and secured in the fibrous adventitious structures as at the commencement (Fig 294) The continuous suture is thus within the interior of the vessels but the knots are outside Should the dilated vein have developed into a definite sac, it may be necessary to remove it, when the opening in the artery may be closed through the space thus made But this is unusual, as a simple dilatation of the vein is much more common If this method can not be readily carried out the vein and artery may be deliberately separated and the aperture in each closed from the outside In some few cases it has been possible to ligature off the communication The next step is to remove the tourniquet or cautiously loosen the temporary ligatures Very often there is considerable bleeding from small branches which have been unobserved or from hidden communications Such hæmorrhage may be alarming and the tourniquet or temporary ligature may have to be tightened again When all vessels have been caught and the field is quite dry the wound may be closed Drainage should be avoided

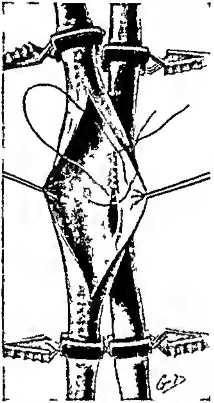

Fig 294 —Matas Bickham operation, with preservation of both vessels leaving no knots in lumen of vein

Ligature of both artery and vein on the proximal and distal side of the lesion—quadruple ligature—is the operation most commonly employed It is simple but is said to be attended by considerable risk of gangrene in the extremities This fact alone is a strong argument in favour of the more modern method just described which indeed is ideal The more long-standing the condition, the better the collateral circulation will be, and the less the risk of gangrene

In performing the quadruple ligature operation it is important to secure as many of the collateral vessels connected with the sac as possible, as these may gradually enlarge and interfere with the permanency of the cure If ligature must be used, rather than reconstruction, the best plan is to combine it with excision of the affected parts of the vessels

In arterio-venous aneurysm of the neck (communication between the carotid and internal jugular vein), every effort should be made to carry out reconstruction, because of the importance of the cerebral circulation. When it is necessary to ligature the carotid the internal jugular vein should also be occluded, whether wounded or not, as this lessens the risk of brain disturbance after ligature of the artery.

In conjunction with ligature, excision of the sac, or varix, may be considered as a safeguard against possible recurrence; but these procedures can only be recommended when the operation of aneurysmorrhaphy is impracticable and when the collateral circulation has been found sufficient, as far as it is possible to test the point.

Each case must be carefully studied and dealt with according to the indications and the conditions found. It must be recognized that in actual practice an operation commenced with the full intention of conservative reconstruction often ends in one of multiple ligature probably combined with excision.

Arterial Aneurysm

Before intervention every aneurysm requires close observation and study. The condition when non-traumatic, is often associated with general arterial degeneration, and not infrequently more than one aneurysm is present. For instance, a peripheral aneurysm may be the cause of the obvious symptoms and signs, but a co-existent aortic aneurysm may be the greater menace to life. The general condition, especially with regard to syphilis, the state of the vessels and of the circulation in the affected part, may all have an important bearing on the management. Sudden changes often mean thrombosis in the sac and may herald gangrene. In peripheral aneurysm leakage is more likely than sudden rupture. Aneurysms of the limbs, near the trunk, or in the chest or abdominal cavities, each demand different types of intervention. In many cases operative interference is associated with great risk but aneurysm is a serious and progressive disease which is fatal sooner or later.

The methods of treatment available are mainly excision, ligature, or some type of endo aneurysmorrhaphy in which the aim is to reconstruct the affected artery or to obliterate the sac without the risks associated with excision. In dealing with peripheral aneurysms *excision* has been very successful and is the operation most generally employed in Britain. I have used it for iliac, femoral, popliteal, axillary brachial and carotid aneurysm with complete success. For aneurysms of the smaller accessible vessels it is always the method of choice. It is perfectly true that there is some risk of gangrene, and that patients sometimes complain of slight weakness of the limb after interruption of the main blood supply; it is to diminish these risks that some surgeons feel it a duty to attempt reconstructive operations.

Ligature is one of the oldest methods and still commands a place in modern practice. The ligature may either be applied just above the aneurysm, as was advocated by Anel in 1710, or at a distance on the

proximal side as introduced by John Hunter in 1785 (Fig 295) Three advantages are claimed for the latter method the vessel can be approached where it is not distorted by the sac, is more likely to be healthy, and there is an intervening set of collateral branches whose presence will ensure that the circulation through the sac is slowed and diminished though not immediately arrested As a result, the clot which forms is firmer and more likely to become safely consolidated Ligature of the femoral artery in Hunter's canal for popliteal aneurysm has proved most successful For the inexperienced surgeon the ligature will certainly be safer than excision In certain situations, and notably for aneurysm of the innominate and carotid arteries, the immediate proximal ligature (Anel) is the only type available In these cases it may be wise to combine this with distal ligature to guard against recurrence of pulsation by means of collateral channels Distal ligature alone has been employed when an approach to the proximal artery has not been possible The idea is to diminish or discourage the flow through the sac but there is the risk that there may be consequent abnormal dilatation on the cardiac side from the dammed up circulation

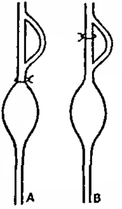

Fig 295 —Proximal ligature
A Immediate (Anel)
B Intermediate (Hunter)

Endo-aneurysmorrhaphy, devised by Matas of New Orleans in 1888, consists essentially of a direct intrasaccular attack with the object of either completely obliterating the aneurysm *from within* or obliterating the sac through leaving the vessel intact The underlying idea is to bring about cure with the least disturbance of the collateral circulation and of the parts about the sac The method is technically more difficult than excision It has been extensively practised in America with much success Writing in 1939, Homans of Boston, one of the most reliable of surgeons, stated " For aneurysms of the great vessels, the obliterative aneurysmorrhaphy of Matas is most likely to succeed and produce a permanent cure " In British practice the method has certainly not displaced the more straightforward excision

Compression of the main supplying vessel has been entirely superseded as a sole treatment, but may be a valuable adjunct when there is recurrent pulsation after ligature It is also a method of encouraging the development of the collateral circulation before surgical interference, for this it may be combined with the use of the Pavex machine

The choice of method.—*Excision* provides permanent cure for, once satisfactorily concluded, there can be no recurrence of the aneurysm at that site It may be a difficult operation fraught with risk to surrounding parts Before it can be undertaken the circulation through the sac must be under complete control In some situations the exposure may present anatomical difficulties but the surgeon must remember that it is not essential to be hidebound by the traditional approach to great vessels In practice the operation has been very

satisfactory and there has been no greater risk of gangrene than with ligature *Ligature* does not provide security from recurrence and the sac is exposed to secondary changes which may be serious As a rule the operation is very simple and can often be carried out under local anæsthesia If it fails the sac can be excised as a secondary intervention or it can be dealt with by incision turning out the contents and packing *Aneurysmorrhaphy* has the advantage that only one face of the sac need be exposed and that the operation can be completed without disturbance of the surrounding parts But it is technically difficult In the hands of Matas and other American surgeons it has proved very successful In actual practice most cases of peripheral aneurysm can be safely treated by excision or ligature

Technique —Before interfering with the circulation of a limb by operation the collateral circulation should be investigated by certain tests The collateral circulation is efficient if (i) the peripheral pulse distal to the aneurysm is absent but the limb is of good colour and nutrition (ii) if when the vessel is compressed just above the aneurysm (*a*) the good colour is maintained or (*b*) the oscillometer reveals pulsation of any degree W Scott Lang in 1887 described a simple flushing test which depended on the appearance of the rosy blush which immediately follows the removal of a tourniquet from the exsanguinated limb in the presence of a sufficient circulation (Hogarth Pringle) Matas in 1907 suggested a further method applicable to lesions of the limb The limb below the lesion—a popliteal aneurysm for example—is rendered bloodless by the application of a Martin s bandage from the toes up to the sac A specially devised tourniquet that compresses the artery alone is then applied just above the sac and care taken to arrest the pulsation entirely The devascularizing bandage is allowed to remain for five to ten minutes according to the age of the patient—the older the patient the shorter the period it is then removed leaving the artery occluded If the anastomotic circulation is satisfactory a blush rapidly descends almost to the toes but not infrequently is arrested for a short time a few inches below the point at which the artery is occluded By degrees however the evidence of returning peripheral circulation may be observed until the extremity of the limb is reached though it may take several minutes

The particular operation must naturally depend upon the situation of the aneurysm its size and form and also upon the nature of the sac wall and the efficiency of the collateral circulation The ideal operative interference would aim to preserve the circulation through the artery affected by Matas s endo aneurysmorrhaphy but cases of aneurysm that are suitable for treatment by this procedure are uncommon

Preparation for operation —For all disabling aneurysms and in elderly people a period of rest in bed is essential The skin of the whole limb should be prepared great care being taken with the foot Usually there is no contra indication to general anæsthesia but spinal

anæsthesia may suffice Local anæsthesia should not be used except for the very small and easily exposed aneurysms The control of the circulation is most important but the main considerations have already been set out (*see* pp 482 *et seq*) Whether for ligature or for local interference, the position of the limb should be carefully considered, for the surgeon must not be hampered in any way For popliteal and calf aneurysms the patient should be turned face downwards and for those about the root of the neck the shoulders should be well elevated and the arm pulled firmly down by the side For axillary aneurysm the body should be almost over the edge of the table or the patient should lie on the opposite side with the arm of the affected side suspended from a mast When excision is to be undertaken incisions must be ample good and unimpeded exposure is the key to success

Excision of the sac —The sac is treated like a non-malignant tumour and enucleated from its surroundings Ample exposure is essential and the whole extent of the sac must be defined so that the main vessels can be readily seen The sac may be separated by gauze stripping, or by the finger or knife or scissors may be necessary Special care must be taken to avoid injury to nerves and other important structures that may be adherent Arterial branches are carefully ligatured outside the sac as they are exposed If possible, the sac should be excised without opening, but this may be out of the question because of its bulk or fragility Sometimes the operation is facilitated by opening, clearing and packing the sac with gauze Parts of its wall may even have to be left adherent to important structures During the dissection the surgeon will have a good opportunity to tie the main artery at its entrance to and exit from the sac

After removal of the sac care must be taken to tie all vessels arterial and venous and a close search must be made for open mouths or retracted vessel ends The vessel clamp or tourniquet should then be cautiously released, for this often reveals an unexpected bleeding-point

The associated vein may be readily identified, or it may be spread out like a ribbon over the sac in which case it is more easily exposed near the origin of the sac It must be caught and tied before being divided

Excision of the sac usually produces cure, but the operation may present difficulties some of which may be avoided by the intrasaccular method, or the surgeon may have to be content with partial excision

The danger of gangrene must never be forgotten and the closest attention should be given to the circulation throughout the limb The collateral circulation should be investigated before or during the operation, and the age and general condition of the patient taken into consideration When the collateral circulation is doubtful or manifestly inefficient, the blood supply may be preserved by direct suture of the ends of the divided artery, or by the venous graft method of Hogarth Pringle (p 496), or by Tuffier s tubes (p 497) All these devices aim

at keeping the main channel open until the collateral circulation has become established

Ligature —The main points about immediate proximal ligature (Hunterian) have already been dealt with (pp 498 *et seq*) If it is decided to apply the ligature immediately on the proximal side (Anel) the surgeon must remember that the vessel may be displaced from its accustomed position by the aneurysm which is often friable and the greatest care must be taken not to rupture its wall in the attempt to expose the main vessel An operation commenced with the intention of applying a proximal ligature very often ends as an excision and probably with the best possible result After immediate proximal ligature pulsation in the sac though greatly diminished may only slowly disappear and the aneurysm may become more prominent for a time Complete failure to cure or recurrence are not unknown When the aneurysm is so situated that excision is feasible this can probably be performed as a secondary intervention with less difficulty than if the artery had not been tied In other circumstances compression may help or the vessel may be re ligatured at another place or distal ligatures may have to be tried.

It may be said that it was failure to obtain a permanent cure of the aneurysm by double ligature that led to complete excision of the sac The fact remains that many cases are cured by the simple proximal ligature after the Hunterian plan This is the simplest method and should be used in all elderly or debilitated subjects but it ought to be combined with ligature of the vein

Aneurysmorrhaphy —There are three methods the obliterative the restorative and the reconstructive

(1) *Obliterative endo aneurysmorrhaphy* —This method is used in place of excision in order to interfere as little as possible with the surrounding structures and thus to preserve the collateral circulation It consists in laying open the sac by a free longitudinal incision after the temporary but secure and complete arrest of the circulation on both the proximal and distal sides The clot is then removed and the interior dried The main step is the occlusion by suture of the orifices of vessels communicating with the sac and its obliteration by superimposed tiers of suture

In obliterating the orifices of the small communicating vessels sutures of silk or chromic catgut on a curved needle without cutting edges are employed The sac is closed by suture commencing at the deeper portion which brings together the lateral walls in the middle line (Fig 296A) Several tiers of continuous or interrupted sutures are thus applied until the main arterial orifices and entire sac are obliterated The skin flaps which are adherent to the peri aneurysmal structures are then closed completely by interrupted sutures

(2) *Restorative endo aneurysmorrhaphy* —This operation is only applicable to sacculated aneurysms where the communication between the sac and the main vessel is small and well defined and the arterial wall is comparatively sound

Complete hæmostasis is secured by a reliable tourniquet. The sac is freely opened, all loose clots are washed out, and the communication leading to the main trunk is closed by a continuous suture of fine chromic catgut or silk, passed through all coats of the vessel wall (Fig. 296B). The remainder of the sac is then obliterated by bringing its surfaces together, as in the obliterative method.

Where the opening of communication between the aneurysmal sac and the artery is large, the greater part of the sac may be cut away,

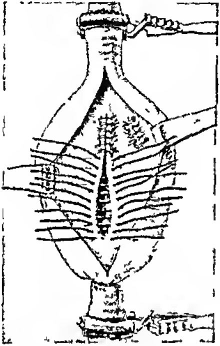

Fig. 296A.—Obliterative endo-aneurysmorrhaphy.

The orifices in the aneurysmal sac are obliterated by sutures, commencing with two silk purse-string sutures at each orifice, followed by separate sutures of catgut.

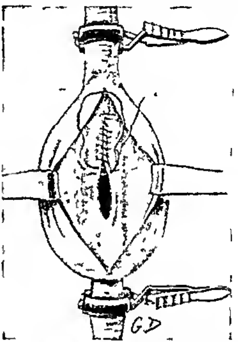

Fig. 296B.—Restorative endo-aneurysmorrhaphy.

Case of sacculated aneurysm showing the single orifice of communication being closed by a continuous suture without obliterating main trunk—a rare procedure.

NOTE.—These illustrations are of necessity diagrammatic. Rubber slings to control the vessels are better than clamps.

leaving just enough of its base to close in the vessel, the object being to preserve its lumen as far as possible. There is, however, considerable risk of clotting at the line of suture, and the thrombus may extend into the trunk of the artery.

(3) *Reconstructive endo-aneurysmorrhaphy.*—Though theoretically ideal, this operation can rarely be performed, and is practically limited to fusiform aneurysms with firm and elastic walls, in which the two openings of the main channel lie close to one another, on the same level, and with an easily accessible sac.

The sac is laid open as before, and a soft, sterile vaselined indiarubber catheter passed upwards and downwards into the lumen of the vessel, and a new channel is reconstructed over it from the sac walls.

The first layer of sutures should be interrupted, the catheter being removed before tying the last suture The remainder of the sac is then obliterated by rows of sutures, as already described In this, as in the previous operation, heparin will help to diminish the risk of intravascular clotting

In all these operations there is usually free oozing from the suture-line as soon as the tourniquet is released but it almost invariably ceases spontaneously in a few moments

After care.—Dressings should be very lightly applied and there must be no constriction lest the developing circulation is impeded The limb should be slightly flexed and laid comfortably on a soft pillow or a water cushion The position should be changed from time to time in order to vary the pressure of its own weight It must be protected from chill by a covering of cotton wool a light blanket or a shawl The returning circulation soon becomes evident and all danger of gangrene should be over by the end of a week When return of circulation is slow intermittent use of dry heat or the Pavex machine may be helpful If the skin is a good colour and the parts are warm the absence of a palpable peripheral pulse is of no moment

Results.—In the absence of complications at the time of operation the immediate results are good Gangrene and secondary hæmorrhage are the greatest risks Matas* quotes an overall mortality of 4 5 per cent In 8 5 per cent of the cases some degree of gangrene developed and in 1 6 per cent secondary hæmorrhage Relapse of the aneurysm occurred in only 1 per cent As in other conditions where there is general arterial degeneration some late deaths from embolism, coronary thrombosis and cerebral hæmorrhage must be expected

AORTIC ANEURYSM

Thoracic and abdominal.—G H Colt, by laborious and sustained investigation into the natural history of this condition, has been able to show that in spite of proper medical management the average duration of life is only about 18 months † The cases reviewed were drawn from the labouring classes, but even among more sheltered lives expectation of life is probably not more than three years Such figures supply some justification for the attempts which have been tentatively made over a number of years to treat these cases by the introduction of wire into the sac in the hope of bringing about cure by clotting and consolidation The risk of embolism has often been urged against this method but Colt s close scrutiny of all the published cases does not support this fear Wiring for aneurysm was first suggested by Moore, but it is only since Colt invented an ingenious apparatus for the precise introduction of the wire that the plan has become practicable ‡ By means of this apparatus several feet of wire can be delivered into the sac in such a way that it opens up like an umbrella A trial of this

* *Annals of Surgery* November 1940 cxii 895
† *Quarterly Journal of Medicine*, April, 1927 xx 331
‡ *Lancet* 1903 ii, 808.

method seems justified in cases of uncomplicated aneurysm when adequate medical management over a period of two months has failed to relieve the symptoms, especially pain and obvious increase in size The method has been used almost exclusively in thoracic and abdominal cases, but there is no reason why it should not be employed in aneurysms near the trunk where other methods of operative interference cannot be employed

Results have been encouraging and in many cases life has been prolonged and made more bearable * In abdominal cases some striking cures have been recorded, patients surviving in good health for 17½, 10½ and 6 years The primary mortality has naturally been high, and many late deaths have occurred from rupture of the aneurysm and from recurrence, but in any event the disease is desperate and distressing and for the most part the treatment has only been carried out late in the disease Colt asserts that " the best chance to cure by wiring is when the patient is in good general health and the aneurysm and the interior of the sac smooth and regular "

Preparation —A preliminary period of rest in bed is essential The diet should be liberal with plenty of fluid Abundant milk will supply the additional calcium necessary

Technique —The special instrument consists of trochar, cannula, container for the wire wisp and ramrod (Fig 297) The steel wire wisps are made in two sizes yielding different surface areas It is of the first importance that the surgeon should see that the apparatus is complete and in good working order, and he must familiarize himself thoroughly with it before essaying the operation The greatest care must be taken to guard against infection In thoracic cases the skin is incised to diminish the risk of carrying infection into the sac In most cases there was either an external swelling or evidence that the sac had reached the parietes in front or behind In one case the aneurysm was exposed and treated after thoracotomy (Finch) In abdominal aneurysms the abdomen should be opened at a convenient spot nearest the maximum prominence of the tumour Adherent viscera should be separated, or omentum with big vessels turned aside, so that the trochar may be inserted without risk of injury to these structures The trochar is not plunged into the aneurysm but is steadily pushed through its wall If firm clot is encountered, the direction of the instrument should be altered to pass by the side of the clot into the interior of the sac where the blood is freely circulating This is tested by removing the trochar, when the blood should spout from the cannula, the wire must never be introduced unless this occurs The cartridge containing the wire is fitted to the cannula and the ramrod is used to push its contained wisp through the cannula into the sac, where it expands This step also must be done slowly and deliberately When the wisp is safely delivered, the cannula is withdrawn As a rule the puncture contracts and there is no bleeding Never-

* Colt *Med Press and Circ.*, Mar 28, 1937 cxciv 493

theless, some operators have taken the precaution of surrounding the site of the proposed puncture with a loose purse-string suture which is tied after removal of the instrument. If oozing persists when the precautionary purse string has not been applied, one or two interrupted

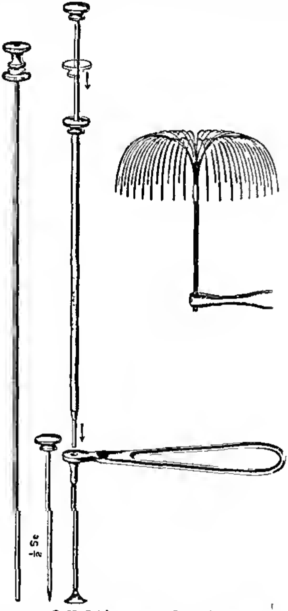

Fig 297 — G. H Colt's apparatus for wiring aneurysm.

sutures of fine catgut or silk in the adventitia will draw the parts together and arrest the flow The disposition of the wire and subsequent change in the size of the aneurysm can be determined by X-ray examination When pulsation has not ceased or pain is un-

relieved the operation may sometimes be repeated with success Wisdom dictates a period of rest after the operation with a generous diet and plenty of milk and if indicated anti-syphilitic remedies The addition of electrolysis has not improved the results

Complications —Contrary to expectation subsequent leaking at the site of the puncture has not been a cause of anxiety In the abdominal cases acute dilatation of the stomach about the ninth day has been rather frequent If anticipated promptly diagnosed and treated by immediate use of the stomach tube it ought not to be fatal

Another method of relief for thoracic aneurysm is **sternal decompression** The sternum is divided or split from the notch well into the body and the halves are forced aside by a bone wedge Patients are said to have obtained comparatively long periods of relief as the result of this intervention

There has recently been a revival of interest in the treatment of aneurysm of the abdominal aorta by ligature or aneurysmorrhaphy Those interested should read the fascinating papers by Elkin Bigger and Matas *

Rupture or suppuration of a peripheral aneurysm, or impending gangrene usually demand amputation of the limb but it may be worth while to try simultaneous ligature of the artery and vein with incision of the sac Bleeding from the sac may be treated after ligature of the artery by laying it freely open and packing the cavity very carefully with strands of lint wrung out of turpentine (p 509)

Cirsoid aneurysm —This condition is best treated by complete excision wherever its situation allows It is most important to make the incisions half an inch from the edge of the aneurysm so that the supplying vessels can be caught where their trunks are well defined Where this method is impracticable all the supplying vessels should be tied It is not always possible to identify the individual vessels and sometimes masses of tissue must be included in the ligatures Even after heroic efforts to control the blood supply some pulsation may persist In these circumstances direct incisions into the part with the coagulating diathermy apparatus may complete the cure

PERIARTERIAL SYMPATHECTOMY

This operation has been frequently performed during recent years but is now being largely superseded by operations directed to the trunk of the sympathetic or its ganglia (Vol II) However it may sometimes be required it has the advantage that it is simple and easy to carry out and if not successful does not in any way interfere with the subsequent performance of one of the other operations mentioned It is usually carried out on the large trunks such as the femoral or axillary or brachial arteries and can readily be completed under local infiltration anæsthesia Its object is to remove the adventitia of the

* Annals of Surgery for November 1940 call No 5 895

artery over an area of about $1\frac{1}{2}$ in of its wall To do this with the least amount of trauma, it is wise to make an ample incision directly over the artery so that the surgeon will not be hampered in the deeper part of the wound Absolute hæmostasis is essential, and all vessels should be divided between artery forceps When the main trunk of the artery is reached small veins will often be found passing over its surface between the *venæ comitantes* or passing to the main vein If it is impossible to avoid these, they should be divided and tied Tiny arterial branches from the main trunk may interfere with the stripping process and must then be divided and tied, care being taken to do this a little distance from their origin If they do happen to be torn flush with the artery, bleeding is smart for a moment or two, but it soon stops spontaneously or if assisted by pressure If it does not, a fine stitch should be introduced at the site of the bleeding The artery having been exposed over the necessary length, the adventitia is rendered prominent by injecting it with a little normal saline which raises it from the artery in a continuous wheal Demonstrated in this way, it can be caught with fine-toothed forceps and clipped away with scissors The process of separation may be assisted by blunt dissection with gauze swabs It is necessary to ensure that the adventitia is removed from the whole of the circumference of the artery If it is difficult to carry out this stripping, or as an alternative, the adventitia may be injected with absolute alcohol as advised by Sampson Handley To make this effective not less than an inch must be injected, and it must be all round the vessel as in the stripping operation It may be carried out conveniently with a hypodermic needle bent to a right angle in a spirit flame, 15 to 20 minims of alcohol will be required In either case the artery should contract locally after the process is effectually completed The soft parts are then allowed to fall together and the deep fascia and skin are carefully sutured

BLOOD-TRANSFUSION

Blood-transfusion has now become an everyday therapeutic procedure, and has an established place in both medical and surgical treatment Its technical difficulties have been very largely overcome and it is a routine in every hospital, but, valuable as it may be, it tends to be overdone, and should never be used without due consideration

Without doubt its greatest field of usefulness is to supply blood in cases of severe hæmorrhage and to counteract the evil effects of blood loss It is also valuable for its hæmostatic effect

It is ideal to transfuse with fresh whole blood, but blood may be used with success after being stored, under suitable conditions, for as long as 10 to 14 days The use of cadaver blood is never likely to become general in this country Modified blood that is blood treated with some anti-coagulant such as sodium citrate, is very generally employed and has proved very satisfactory In the present conflict a great deal of research on the problems of blood-transfusion has been

undertaken and much is being discovered that may turn out to be of great practical importance At the moment of writing it is safe to state that whole fresh blood will fulfil every indication for which transfusion may be required It is by far the best restorative in hæmorrhage Blood serum is valuable where there has been great loss of fluid, in shock, and in burns Dried blood is being tried for its convenience of storage and transport

General remarks.—Whatever method is being used careful observation should be kept of the blood pressure and pulse during and after transfusion as these records supply data by which the progress of the patient can be determined In massive blood loss the best guide to the patient s condition is the blood pressure and, in chronic hæmorrhage the hæmoglobin index

In performing blood transfusion for hæmorrhage where immediate operation is necessary a tourniquet should always be applied to a wounded limb or bleeding elsewhere controlled before the transfusion is commenced, otherwise the sudden raising of the blood pressure is apt to re start the bleeding

In serious intra-abdominal hæmorrhage it is a useful rule never to begin transfusion until just before the operation so that the bleeding point can be dealt with as soon as the abdomen is opened This practice was adopted during the War (1914–18) in consequence of certain unfortunate experiences in which the patient rapidly weakened and died a short time after transfusion

It must not be forgotten that blood-transfusion is not without risk, and that sudden death may occur even when every care and precaution have been exercised

Grouping and matching —It is important to remember that the serum of the *patient* must not agglutinate or hæmolyse the red cells of the *donor*, though whether or not the donor's serum alters the red cells of the recipient is a secondary matter and indeed is unlikely on account of the degree of dilution But several workers have recently called attention to the possibility of the *cells* of the patient being agglutinated and hæmolysed by the *serum* of the donor in the presence of relative degrees of circulatory stasis such as may obtain in a state of severe *collapse, and as a result of the presence of a disproportionately large* concentration of the donor s serum in the part of the circulation near to the site of transfusion

If an incompatible blood is used severe symptoms may arise, such as cyanosis, rapid respiration, rigors, pain in the back, rise in temperature and pulse-rate and hæmoglobinuria Cases have ended fatally within a few hours of the transfusion

In these days there is no excuse for risking the transfusion of incompatible blood In hospital practice most patients are grouped and suitable blood may be readily obtained from a blood bank or an accredited donor But even so the suitability of the blood should always be confirmed by direct matching and in circumstances where the blood group cannot be ascertained this method alone is reliable

A simple method of *direct matching* is to take 2 or 3 c c of blood from the recipient and allow it to clot, or to separate the serum in a centrifuge To a drop of this serum is added a small drop of blood taken from the donor s ear and suspended in 1 05 per cent citrate solution If any agglutination is found, the blood is rejected If this test is negative, the blood may be regarded as satisfactory It is, however, wise to wait for ten minutes and to examine the mixture with a lens or microscope before deciding that there is no agglutination

Methods of blood-transfusion.—Of the many methods in use it is difficult to say which is the simplest and most efficient With practice the operation becomes comparatively easy, and any method found satisfactory should be adopted

The blood, whether whole or citrated, may be run into the vein by gravitation from any simple container A glass funnel with a length of rubber tubing and hollow needle are the minimum requirements An inverted graduated bottle with an airway in the cork or a special flask such as the Keynes model is usually employed The sterility of all the apparatus is essential and no chemical substance should contaminate the blood New rubber tubing should be soaked in distilled water and carefully boiled at least twice before being used for blood-transfusion Whenever suitable veins can be found they should be punctured through the skin Sometimes it facilitates the introduction to make a tiny incision through the skin with a knife A sharp needle and a visible vein are the essentials for successful puncture When the veins are collapsed or very small or are buried in the subcutaneous fat, it may be impossible to strike the lumen with the needle In these circumstances an incision should be made over the known course of a vein like the median basilic or the internal saphenous If the patient is not anæsthetized the line of the proposed incision should be infiltrated with novocain The incision need not be more than an inch long If the skin is drawn aside away from the vein, it can be boldly divided through its whole thickness When released, the incision should be just over the vein, which should be isolated by blunt dissection with the end of an artery forceps It may then either be punctured *in situ* with the hollow needle or it may be nicked so that a cannula can be introduced In the latter case two ligatures should be passed under the vein, one to tie the vein below and the other to tie the cannula into its lumen When the transfusion is finished and the cannula withdrawn, the vein should be tied and the skin incision carefully sutured Much care should be taken to guard against infection in carrying out this little operation Local suppuration and septic phlebitis sometimes occur and are troublesome and discreditable complications If a cannula is to be left in the vein for some time it must be packed round with antiseptic gauze which should be fixed in position with strapping Should the cannula be left *in situ* for some hours the edges of the incision may be drawn together with strapping after its removal and the wound dressed antiseptically

Continuous or drip transfusion requires a double container so that the apparatus may be irrigated with saline from time to time or saline substituted for the blood. A drip bulb is introduced on the flow way so that the rate may be observed and regulated. About 40 drops to the minute is the usual rate and a total of 1,700 c c of blood is probably as much as is ever likely to be necessary.

Citrate method.—This is probably the simplest and is certainly an efficient method. The necessary apparatus consists of a graduated bottle holding 850 c c (30 oz), and two or more needles or cannulæ, with rubber tubing. Keynes's modification of Robertson's flask is very convenient. The simple plan adopted in introducing saline into a vein may be followed. About 180 c c of 1 05 per cent solution of sodium citrate is placed in the bottle which is kept in warm water at 100° F. The quantity of blood it is proposed to transfuse, usually 550 c c, is drawn off from the donor's vein by needle or cannula and mixed thoroughly with the citrate solution by constant stirring with a glass rod. There should be no need for filtering if intimate mixing of the blood and citrate solution are assured. As a rule, the proportion of blood to solution is five or six to one. Although it is best to carry out the transfusion immediately, the citrated blood can be kept for several hours at a suitable temperature and used with success.

Whatever method be employed, it is of the greatest importance that *the blood should be infused slowly* so as to allow for the proper adaptation of the cardiovascular system to the increased quantity of circulating fluid. *Never* should less than 30 minutes be allowed for the infusion.

Re-infusion of the blood lost at operations can be carried out if it has not become contaminated. For instance, the blood from the abdomen in a case of a ruptured spleen or liver or ectopic gestation, may be collected, citrated, filtered and re-injected with every prospect of success.

Reactions, such as rigors, fever, vomiting, precordial distress, irregular pulse or collapse, may occur. Some of these may be due to blood incompatability but it should be possible to guard against this by care in matching. Particles of debris or dead bacteria may be the cause, and this emphasizes the need for scrupulous care in cleansing the apparatus after use and re-cleansing and sterilizing before use. Too rapid transfusion or too great an amount of blood may cause cyanosis, dyspnœa or a sensation of suffocation.

VENOUS SYSTEM

For the ligature of veins fine silk is better than catgut. The walls of these vessels are thin, and catgut ligatures are apt to slip. Silk has a much better bite. This particularly applies to lateral ligatures for the occlusion of holes in big veins.

Injuries to the portal vein illustrate the problems associated with

the conservative surgery of veins This matter is dealt with in the section on the liver and its excretory apparatus at p 781 The same problems may arise in connection with the inferior vena cava when that vessel is injured during the removal of renal or retroperitoneal tumours

Varicose Veins

Before deciding to interfere it is necessary to be satisfied that the obvious varicosity is the cause of the symptoms of which the patient complains

The reasons for the treatment of varicose veins of the leg are —

(1) Disability arising from pain or other discomfort especially aching and cramp on standing
(2) Secondary changes resulting from longstanding venous congestion such as œdema eczema or ulceration
(3) Hæmorrhage
(4) Recurrent phlebitis
(5) The exigencies of the public services

Since the publication of the last edition of this work much additional experience of sclerosing injections has shown that there is still room for operative measures in some cases When the internal saphenous in the thigh is markedly varicose it must either be divided and ligatured just below the saphenous opening (Trendelenburg operation) or divided the upper end ligatured and the lower part treated by retrograde injection or the whole vein removed by dissection or by the extraction method of Babcock It is also necessary to operate for the removal of a femoral varix resembling a hernia for specially large varicosities such as are sometimes seen in the thigh or in those cases where injection treatment fails In many cases a combination of injection and operation is required for complete success Before the injection method was introduced thorough removal of the veins usually produced cure

When operative removal is necessary the veins must usually be dissected out

Incision should be directly over the course of the veins When they are very large and adherent to the skin it is easier and better to remove a strip of skin with the vessel If surgical removal is to be relied upon entirely the whole internal saphenous should be excised by one of the methods described below

It may also be necessary to interrupt the blood-stream in septic phlebitis with rigors For this purpose it is enough to expose to ligature and to divide the main vein between the focus and the trunk. In both the upper and the lower limb the ligature of the vein should be carried out as far away from the septic focus as possible

The object both of operations for the actual removal of the veins and their obliteration by injections is to divert the venous circulation from the superficial to the deep veins It is therefore important before undertaking treatment to determine the condition of the latter

Injection method.—This plan is contra indicated (*a*) if there is thrombosis of the deep veins, (*b*) in the presence of acute phlebitis or other septic condition (*c*) when the varicosity is due to physiological congestion, as in pregnancy, (*d*) in advanced cardiac or renal disease

The solutions employed have been numerous and varied I have always used quinine and urethane (quinine hydrochlor 4 gr urethane 2 gr, and doubly distilled water, 30 c c) It is well to commence with ½ c c to determine whether or not there is a special idiosyncrasy for quinine The usual subsequent dose is 1 to 2 c c Sodium morrhuate in 5 per cent solution is now more generally employed and has proved most satisfactory It is wise to begin with a trial dose of 1 c c, but if there is no severe reaction doses of 3 or 4 c c may be subsequently employed With either solution such doses may be expected to sclerose a length of 4 in, half above and half below the puncture The injections are never to be made above the level of the middle of the thigh

The interval between injections should not be less than one week The number of injections necessary depends upon the extent and the size of the veins to be treated and the reaction of the individual Sometimes one injection will thrombose a considerable length of the internal saphenous In an average case 4 to 6 injections will be required The result is to thrombose the contents of the vessel Later this thrombus becomes organized and finally leaves a hard cord which may remain permanently or may gradually disappear

The actual injection is made with an ordinary small Record syringe with a fine, very sharp needle The skin is sterilized with alcohol and the needle is slowly and gently thrust into the vein It is easier to introduce the needle with the patient standing as the veins are then prominent, but nervous subjects are better lying The veins may then be made prominent by a loose tourniquet, which is removed when the needle is known to be within the lumen It is generally conceded that it is better to inject when the veins are empty

It is absolutely essential to be certain that the lumen has been reached before the injection is made The only way to demonstrate this is to withdraw some blood into the syringe Once the lumen is reached the injection is slowly made but the needle is not withdrawn for a few seconds after completion As it is withdrawn a sterile pad must be slipped over the puncture and held firmly for a minute or two This is in order to prevent escape from the vein into the subcutaneous tissue The puncture is then painted with iodine and the leg is supported by a crêpe bandage which should be worn until the next injection The pressure of this bandage will keep the vein empty for some hours Beyond a slight burning sensation there is no discomfort and, as a rule, the patient can walk away *If uneasiness persists, rest,* elevation of the limb and aspirin will bring relief

It can hardly be said that there are ever accidents, but there may be slight anxiety from emotional faintness Some patients feel buzzing

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in the ears and have been known to taste the quinine almost at once These symptoms do not occur with sodium morrhuate Subsequently there may be stiffness and soreness for a day or two and there is sometimes actual phlebitis with redness and swelling over the vein As sequelæ there may be some œdema of the leg and the thrombosed vein may remain tender A troublesome type of thrombo phlebitis may persist Cellulitis and ulcer at the point of injection are both recognized as being due to escape of the solution into the tissues around the vein They are fortunately rare and avoidable sequelæ

Danger appears to be very remote for many thousands of injections are made every year without untoward consequences Pulmonary embolism has occurred but no more frequently than as a complication of untreated cases (7 times in 53 000 cases Bailey and Love)

Results —In properly selected cases these are very good provided the whole of the affected area is treated and any necessary auxiliary operation carried out

Operation Removal by dissection —This method was universally practised before the introduction of sclerosing injections It may be used as an alternative to the injection method but is generally reserved for dealing with very well marked varicosity of the internal saphenous in the thigh or for varicosity of the whole vein especially in young subjects It may also have to be used when there is recurrence after injection To be successful the removal must be especially thorough from the groin to the knee When the whole leg is to be dealt with the operation may take a couple of hours or even more General or spinal anæsthesia is required In any case the skin of the whole limb should be prepared and the greatest care should be taken to preserve asepsis When the veins are very dilated the leg should be elevated an inclined plane on the operating table is more satisfactory than suspension If the veins are not very prominent it is a good plan to mark out their course with carbol fuchsine before the skin is prepared and while the patient is standing One long incision may be made over the most prominent part of the vein extending from the saphenous opening to just about two inches above the ankle it is much better however not to carry the incision behind the knee but to make separate incisions in the thigh and leg If it is necessary to remove the portion of vein by the knee this can be done by the subcutaneous method (*vide infra*) The skin edges should not be dissected further back than is necessary to expose the vein completely and in any event for not more then about an inch If it is difficult to reach all the veins without undermining the skin two or more separate incisions are better than flaps as there is a risk of their sloughing All lateral branches should be caught before being divided the fat being pushed aside with the points of artery forceps Often the veins are friable and the branches break off and retract If they cannot be readily caught they may safely be left alone for the pressure of the bandage will arrest the bleeding At the upper end the main trunk should be divided and tied

about an inch below its junction with the femoral All arterial bleeding must be arrested and the skin edges carefully approximated by suture For rapid healing perfect wound suture is essential

When the posterior or short saphenous is affected it is only necessary to remove two or three inches at the lower part of the popliteal space Vertical incisions in this region are to be avoided when possible A transverse incision across the lower part of the space will suffice if the edges are well retracted The vein will be seen just underneath the popliteal fascia and can be readily removed When there is ulceration care should be taken to diminish infection before operating, and in any event the incisions for vein removal should stop short of the edge of the ulcer by a couple of inches

Subcutaneous removal —This method is associated with the names of Babcock and Mayo The idea is to remove a considerable length of vein between two short skin incisions In the Babcock method, which is the best, the vein is enucleated by inversion a special instrument being required (*Fig* 298) By this means long stretches of

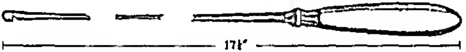

Fig 298 —Instrument for the removal of varicose veins by the subcutaneous method The probe is made of malleable copper (Grey Turner s model)

vein—from below the knee to the middle of the thigh, or from the lower part of the thigh to the saphenous opening—can be removed It is only necessary to make an incision an inch long exposing the vein on the inner side a few inches below the knee The vein is isolated and opened so that the probe can be introduced into its lumen The probe is then pushed gently upwards as far as it will carry and another short incision is made on to this point The vein containing the end of the probe is isolated, and a long silk ligature is tied tightly round the vein, biting into the notch in the probe The vein is then ligatured and divided just beyond the end of the probe The probe is withdrawn from below carrying the inverted vein and the silk ligature with it The isolated vein is then ligatured and cut away Sometimes it comes away very easily, but if it does not, the long silk ligature used to tie the vein to the probe is held taut from the upper incision while the vein is withdrawn with a series of jerks on the probe Of course the lateral branches are torn across, but the bleeding is easily controlled by a firm bandage

If the vein breaks when only a short length has been inverted the probe may be re-introduced up to the point where it broke, and here a short incision must be made so that the vein can be again tied to the probe The method is very useful for removing the saphenous trunk. When the distance is not too great the probe may reach from

just below the knee to the saphenous opening Usually this vein has to be removed in two sections

The method is not generally suitable for the veins below the knee nor is it likely to be successful for very big veins or where there have been attacks of phlebitis or previous treatment by injection

After care —It is wise to keep the patient in bed until the wound is healed After extensive dissection four days or more may be necessary For three or four weeks the limb should be supported by a crepe bandage and should be kept elevated when the patient is resting

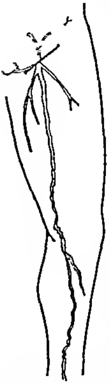

Fig 299 Incision recommended for Trendelenburg s operation

Resection of vein at saphenous opening —This is the **Trendelenburg operation** The object is to ligature and divide the great saphenous just below its junction with the femoral It is considered best to excise about an inch of the vein An oblique incision is made across the upper and inner part of the thigh about an inch below and parallel with Poupart s ligament (Fig 299) If there is much subcutaneous tissue it is easier to find the vein through the oblique incision and in any case it has the advantage that a posterior branch that would probably be missed with a vertical incision can be found and divided This branch should always be sought The main trunk should be carefully exposed and sufficiently separated from its bed to allow a ligature to be passed around it In defining the upper end care must be taken not to drag up the femoral vein The lower end may be caught in a clamp and tied after division The actual division should be made half an inch beyond the point at which the ligature is applied so that there can be no possible risk of the latter slipping Some enlarged lymph nodes may be encountered about the saphenous opening these should be disturbed as little as possible The wound is carefully sutured care being taken to bring the fat and deep fascia together

Resection of saphenous with retrograde injection —This method may be used when the veins below the knee have been successfully sclerosed by injection but the saphenous in the thigh remains patent and varicose It is also an alternative to removal of the thigh veins by dissection The patient should be in hospital Local anæsthesia will suffice The trunk of the vein is exposed just below the saphenous opening and is isolated for a couple of inches A ligature is applied half an inch from the femoral vein and the trunk is clamped across about an inch lower down the intervening portion being excised The sclerosing solution is injected into the lower end In this method

the lower end of the vein may be of so large a lumen that it is difficult to tie it about even a large-size Record needle. A special nozzle may be used, or the vein may be ligatured and the injection delivered into the distended parts below by puncture with an ordinary-size hypodermic needle. The 5 per cent sodium morrhuate solution is used, and up to 10 c c may be injected. The wound should be swabbed with saline to remove traces of the sclerosing solution and should then be carefully sutured, care being taken to bring the fat together to obliterate dead spaces. The thigh is mildly compressed with bandage or strapping. The patient may get out of bed the next day but should remain under observation for two or three days.

LYMPHATIC SYSTEM · ELEPHANTIASIS

Operative treatment devised to relieve lymphatic stasis in cases of elephantiasis has undergone modification and now it may be said that Lang's operation, modified according to the methods of Kondoleon and Sistrunk, is a surgical procedure that offers some prospect of success, especially in cases in which the lower extremities are affected. I have seen great improvement after operation but never complete cure, and relapse is not uncommon. But, as a rule surgical intervention has only been carried out at a late stage and when there are secondary changes in the lymph sodden tissues. Since the malady is progressive and invariably leads to a burdensome disability earlier and more radical surgical treatment is justified.

Lang* made a long incision down the thigh and leg carried right to the bone. The periosteum was detached from the bone and holes were trephined through to the medulla, and into these portions of the detached periosteum were inserted. This method has been superseded by that of Kondoleon† who also used long incisions on both the outer and inner aspects of the limb and through these removed large sections of subcutaneous tissue, fat and aponeurosis so that the muscles were left quite bare at the bottom of the large wound. The incisions were most carefully closed without drainage.

Sistrunk's operation ‡ which is very similar, begins with a long elliptical skin incision extending from the trochanter to the external malleolus. The skin is then reflected towards both back and front to the extent of an inch or two, to permit the removal of a large amount of subcutaneous fat. This fat, the skin ellipse and a strip of deep fascia is removed, the wound being sutured without drainage; a like procedure is carried out on the inner side of the leg. In each case the aim is to remove large sections of the œdematous and hypertrophied tissue and to establish free communication between the superficial and deep lymphatic systems thereby restoring the lymph drainage. Homans (1939) asserts that lymph drainage cannot be renewed and that any benefit following operations of the Kondoleon type is derived from

* *Centralbl. f Chir.*, 1911 xxxviii, 3 153
† *Munch med Woch.*, 1912 lx 1915
‡ *Collected Papers Mayo Clin.*, 1918 x 943

the removal of lymph-sodden tissues. The limited success of these operations even when most thoroughly and carefully carried out supports this contention. In conformity with this view Homans advocates an operation designed to remove the greatest possible amount of the tissues between the skin and the deep fascia all around the limb. After completion the skin denuded of its subcutaneous tissue lies directly on the bared muscles and bone. The operation is carried out in at least two stages and from incisions on either side of the limb. As a rule only the leg below the knee is dealt with as this is the great reservoir of fluid and where the maximum effects of its accumulation are found.

These operations are not free from risk and unless great care is taken they may be followed by severe shock. The patient should be carefully prepared by a period of three or four weeks in bed with the limb elevated and bandaged from the toes upwards. During this period most painstaking attempts should be made to sterilize the skin. The actual operation should be done slowly and carefully so that all vessels may be caught and tied as the operation proceeds. A tourniquet is sometimes advised but the upper part of the thigh is often so swollen that it is difficult to compress the vessels. If the patient is not in good condition only one side of the limb should be done at a time. After operation there should be no hurry to get the patient out of bed and a mildly elastic bandage should be worn for some months.

In an attempt to improve the results of operative interference Gillies and Fraser devised a method of bridging the area of lymphatic block by means of a long strip of healthy skin and subcutaneous tissue with its lymphatics. This skin bridge is cut from the upper extremity. A bed is prepared extending from the affected thigh to the flank, and into this the pedicled flap is most carefully sutured. When it has firmly healed into position the flap is detached from the upper extremity. The area on the arm from which the bridge is secured must be carefully repaired and may require skin grafting. The operation is potentially a severe one which must be carried out in stages. In a few cases the results have been encouraging.

When there is chronic ulceration or grave sepsis it may be safer to tie the external iliac artery. Great improvement often follows and if necessary the Kondoleon operation may be done later.

CHAPTER XII

PRINCIPLES OF THE OPERATIVE TREATMENT OF MALIGNANT DISEASE

By W SAMPSON HANDLEY

THE fundamental starting point for the operative treatment of malignant disease is the fact that cancer is a disease of local origin spreading gradually to distant parts It is not a systemic or blood disease, as the earlier pathologists thought if it were the surgeon would have no part to play in its treatment It may be admitted that operation is a clumsy weapon wherewith to fight the invisible and microscopic extensions of such a subtle disease The fact remains that at present for some varieties of cancer it is still the only trustworthy weapon Radiological treatment has however, in some directions made great strides Useful palliative effects and an occasional apparent cure have followed the implantation of radium tubes in cancer of the prostate and of the pancreas—forms of growth which most surgeons regard as essentially inoperable For certain forms, particularly for most cases of carcinoma of the tongue, mouth throat, lip and penis, radium treatment has established its definite superiority to operation In other cancers, *e g* of the cervix, the two methods compete on level terms In yet others, as in cancer of the breast, radium treatment has become a reasonably hopeful alternative which may be offered for the patient's choice Radium appears to have definitely failed hitherto for growths of the stomach and bowel though in cancer of the rectum it may score a rare success Even in primary growths amenable to radium operative excision of affected glands is usually necessary

We trace briefly the various stages through which cancer surgery has passed

Simple excision of the primary growth.—As soon as the progress of clinical observation had made possible the recognition of malignant growths, the surgeon followed his natural impulse to cut out the lump Velpeau's description of his method of operating on breast cancer, dated 1853, may be taken as illustrating this primitive method "Plunging in a straight bistoury,' he says, "I, with one stroke, divide all the tissues to the lower surface of the tumour Two of these parallel incisions enable me to include the tumour in an ellipse, and to separate it like a slice of melon In this way the wound is more uniform and the proceeding more rapid"

Operations of this character, restricted to cutting out the lump, have from the earliest times been followed by a very occasional success,

probably because the removal of the bulk of the malignant tissue enables the natural resistance of the body to deal with what is left But the method is like attempting to extirpate turf with a mowing machine, and little more hopeful

It might be thought that simple excision of the obvious lump is nowadays never practised This is far from being the case In one week recently, two cases in which it had been used for breast cancer, the greater part of the breast being left behind came under my observation Such cases are the handiwork of the "occasional surgeon But in melanotic sarcoma the same simple operative recipe is still followed, even by trained surgeons, and with deplorable results There are, of course cancers trenching closely upon vital and irremovable organs in which a close excision of the lump represents all that is surgically possible cancer of the œsophagus or prostate may be examples One would however, rather infer that these growths are essentially inoperable than admit that restricted excision of a cancerous lump should ever be practised

Charles Moore s paper on ' Inadequate Operations * affords material for judging the results of "cutting out the lump in breast cancer Among ten cases in which a cancer was excised from the breast the disease returned in nine in the remaining portion of the breast and in one in the axillary glands alone

It has been suggested that the primitive method of limited excision would be satisfactory if supplemented by buried radium tubes round the periphery of the operation area Some surgeons especially Mr Duncan Fitzwilliams are trying the combination, but its value cannot yet be assessed

Excision of the primary growth with a definite margin of healthy tissue—The next stage in the surgery of cancer, based on the unsatisfactory results of the primitive method was free excision of the primary growth with a margin of healthy tissue In breast cancer this extension of the operation was described as an "amputation of the breast The use of the term ' amputation indicates a lopping off of the organ without regard to anatomy or pathology In mammary cancer little improvement in results was secured Moore states that in three cases of complete removal of the whole breast, return of the disease cutaneously or subcutaneously confined to one of the flaps, took place in two in the other the disease recurred in the axillary glands

Simple free excision of the primary growth has not been entirely superseded It remains the method of choice for some malignant tumours the method of necessity for others It is adopted in rodent carcinoma which has no tendency to disseminate It is suitable for dealing with malignant growths originating in areas where dissemination is prevented by previous destruction of the lymphatics as in lupus carcinoma and some X ray carcinomata , and for the fibro-sarcomata

* *Med.-Chir. Trans* 1867 l, 245

which have little tendency to disseminate Sometimes it may be justifiable as a palliative to remove the offensive and obvious external growth until the patient succumbs from dissemination but untroubled by local recurrence In many internal cancers, free excision of the primary growth may be all that is surgically possible

Monobloc removal of the cancer and the affected glands enclosed in a sheath of normal tissue.—The beginning of a third stage of cancer surgery is to be traced in the paper read before the Royal Medical and Chirurgical Society in 1867 by Moore, who was then Surgeon to the Middlesex Hospital He showed that recurrence after the operation is due, not to an organic or constitutional taint, but to imperfect removal of the primary growth and its surrounding satellite nodules He insisted that the growth, with all its ramifications, must be removed in one piece and must not be seen or cut into during the operation He enunciated the necessity in every case of removing the whole breast, along with unsound adjoining structures—skin, lymphatics, fat, pectoral muscle, and axillary glands After freely removing the unhealthy skin, he undermined the skin flaps so as to detach the breast from its circumference towards its centre He did not, however, state precisely how he would define " unsound adjoining structures ' requiring removal, nor did he give an exact description of his operative method It was perhaps for these reasons, or because of the danger of extensive operations in the pre-Listerian period, that his paper failed of its full effect Twenty years later, when Mitchell Banks advocated the routine removal of the axillary glands in breast cancer, only one speaker was found to support his opinion Gross, in 1888, from statistical studies, strongly supported Banks's views

Is removal of the glands in one piece with the primary growth essential to the success of the operation ?—Gross, who was one of the first to advocate removal of the lymphatic glands in carcinoma of the breast, used to pick out the glands from the axilla through a separate incision Such a dissection was necessarily incomplete, and involved the division of possibly infected trunk lymphatics To Halsted is due the adoption, in breast cancer, of the monobloc method of operation, though its desirability had been earlier advocated by Moore

Rationalization of the monobloc operation —It is one thing to assert the desirability of the monobloc operation, it is another and a much more difficult thing to practise it, for the surgeon has no ocular evidence of the microscopic extension of the growth Until recent years no systematic study of the mode of spread of cancer had been undertaken, or, at any rate, there was no general conception of its mode of spread The establishment on a sure basis of the permeation theory of dissemination enables rational methods of monobloc removal to be planned with a good prospect that they will attain their object, though much remains to be done in investigating the spread of primary cancer in the internal organs No surgeon can deal properly with cancer who has not made a study of lymphatic anatomy and the mode of spread

The permeation theory was first worked out for breast cancer and for melanotic sarcoma Accordingly though it is applicable generally to carcinoma and to some sarcomata its consideration is deferred to p 502

The object of the monobloc method now usually accepted as desirable is to ensure the removal of the trunk lymphatics connecting the primary focus with the infected glands If it could be shown that these trunk lymphatics are free from cancer-cells then it would be safe to remove first the primary growth with the permeated area around it and secondly in a separate mass or by a separate operation the infected glands remembering however that an infected gland is itself a focus of permeation

There is evidence that trunk lymphatics along which cancerous emboli have passed from smaller permeated lymphatics are not thereby infected The strong lymph stream of these larger lymphatics scours them and transports to the nearest gland all the cancer-cells which pass along them As soon however as the entire catchment area of a trunk lymphatic is choked by permeation of the small vessels which compose it the lymph-current of the trunk lymphatic is arrested Plugs of cells intruding into the trunk from permeated tributaries are no longer swept away On the contrary they continue to proliferate easily within its wide lumen and the trunk lymphatic itself becomes permeated Such permeated trunks may sometimes be felt in a late stage of breast cancer as nodular cords passing to the axilla In rare cases the thoracic duct itself is in this way converted into a solid cord of growth

The answer to the question whether monobloc removal of the glands is indispensable evidently depends on the period of the disease at which trunk permeation begins This probably varies according to the degree of cohesion between themselves possessed by the cancer-cells If they cohere loosely as in most cases of glandular cancer trunk permeation will be deferred If they cohere closely as in squamous celled carcinoma the lymph-stream may fail to purge the trunk of the invading cylinder of cancer-cells and trunk permeation begins In most cases of breast cancer clinically regarded as operable trunk permeation is still absent On the other hand in cancer of the lower lip trunk permeation is certainly present in quite early case this is indicated by the frequency of recurrence at the apex of the V in V-shaped excisions The same is probably true of the tongue

On the whole it may be concluded that while monobloc removal of the growth and glands is not in all cases essential it is nevertheless most desirable in the absence of a dominant contra indication

If as in cancer of the tongue the primary growth is situated in a septic area which cannot be shut off separate removal of the primary growth and of the glands is usually right The risk of leaving permeated trunk lymphatics is outweighed by the more immediate risk of sepsis in a large cervical wound The operator may legitimately hope in such cases that permeation of the trunks has not yet begun

He may also rightly urge, as Jamieson and Dobson point out* that it is really impracticable to remove, even by a monobloc dissection all the trunk lymphatics running from a cancerous focus in the tongue

In 70 cases of tongue cancer operated upon by Butlin—hardly any of them monobloc operations—there were 29 successes These figures indicate either that in over 40 per cent of operable cancers of the tongue there is no trunk permeation, or that in some cases the permeated trunks remaining after operation are destroyed by inflammatory reaction or otherwise They afford no reason for impugning the value of the general principle of monobloc operation, which is well established, and only to be violated for sound reasons such as are present in the case of lingual cancer Apart from the reasons already urged in its favour, the monobloc method minimizes the risks of implantation

Radiation-excision method.—The monobloc operation has of late ceased to be the standard method of dealing with many cancers such as those of the tongue mouth, lip and penis The primary growth is no longer excised but is dealt with by the implantation of radium needles The glands are excised by a separate systematic operation Regaud has found that radium treatment of the glands in cancer of the tongue does not give adequate security against glandular recurrence To secure the best results the gland operation must be very complete and extensive not confined to the removal of glands which are visibly or palpably enlarged

This is no new doctrine, it was insisted upon by Butlin many years ago If in cancer of the tongue, only the enlarged glands—say the tonsillar, submaxillary or submental glands—are removed, recurrence in the lower glands of the main deep cervical chain is almost invariable

It is not difficult to account for the unsatisfactory results of restricted gland operations Briefly, infection of a gland with cancer-cells occurs some time before there is any clinical evidence of it Recurrence is nearly certain unless the apparently normal glands adjoining the enlarged ones are removed The ideal is complete removal of the glands of the affected region The task is no light one, and is impossible without a detailed working knowledge of lymphatic anatomy The old rule of thumb that the glands requiring removal are those which the operator finds enlarged must be abandoned Along with it must go the idea that gland operations can be dispensed with when there is no clinical evidence of glandular invasion

Implantation of cancer during operation.—An important object of the monobloc operation is to prevent the setting free of cancer-cells in the wound It is known that an animal suffering from spontaneous cancer can be readily inoculated with a fragment of its own growth In France the experiment has actually been made with success on the human subject It is evident, therefore, that if a cancer is cut into during removal a risk of accidental inoculation of the wound at once

* Brit Journ Surg July 1920 viii, 80

taken is to embed in the floor of the wound a sufficient number of radium needles effectively to radiate the suspected area It is for instance not rare in operating upon the supraclavicular glands for breast cancer to find a fixed and irremovable mass at the angle of union of the internal jugular and subclavian veins Such a mass may be transfixed by a radium needle when exposed but could not be treated effectively by blind methods

In 1931 during an operation for recurrent glands in tongue cancer in a man of 65 after the primary growth had been suppressed by radium a degenerate gland near the root of the neck ruptured and discharged its contents over the wound The wound was washed out first with perchloride of mercury 1 in 1 000 to coagulate the albumin of isolated free cancer-cells and then with saline to prevent the injurious action of mercury upon the platinum of the radium needles About ten radium needles of 2 and 3 mg well distributed were left in the wound for a week There is still (1942) no recurrence and the patient has become the father of an only son If the skin flaps are thin radium needles must not be left too close to their deep surface

X rays in the prevention of implantation —A course of X rays should always be applied after healing in a malignant growth which is susceptible to their action Their value may be doubtful in refractory growths such as squamous celled carcinoma In other cases it may decide the success of the operation Thus for instance it seems almost certain that a prophylactic course of X rays would have prevented the development of the implantation nodule in the abdominal wall which proved ultimately fatal in the case of gastric carcinoma referred to above (p 546)

Since the last edition of this work was published I have met two other cases of implantation recurrence in the abdominal wall one following the removal of a malignant ovarian tumour the other the the removal of a carcinoma of the cæcum In the first case buried radium treatment supplemented by X rays suppressed the recurrence In the second radium failed and excision became necessary

PATHOLOGY AS THE FOUNDATION OF CANCER SURGERY

Many surgeons developing surgical methods of dealing with cancer have largely trusted to a comparison of the results of various empirical operations In this country Sir Harold Stiles was the first to perceive the necessity of founding operative procedure for cancer upon precise pathological studies Stiles s researches on the anatomy of the breast and on the pathology of a hundred excised breasts led to the description by Cheyne and himself of a method superior to that of Halsted in its insistence upon the necessity for a wide removal of the circum mammary fascia and in its relative economy of skin Stiles however failed to lay stress upon the routine removal of the lower half of the great pectoral which was rightly demanded by Halsted

arises The late Sir C Ryall ('Cancer Infection and Cancer Recurrence') drew special attention to this danger He quotes several interesting cases In one case a stitch hole in the operation scar was the site of the recurrence In a second case, where the clavicle was divided to reach infected supraclavicular glands, the wound healed but the bone became the site of recurrence In a third case, an operation for a small tumour of the breast, the whole chest within two months of the operation was involved in cuirass cancer, in this case the operator had used the same knife for making an incision into the growth and for its subsequent removal Diffuse infiltration of the neck may rapidly follow rupture of an epitheliomatous gland during operation

Ryall collected a series of 25 cases of implantation which had come under his observation The most striking case I personally have seen was that of a lady upon whom a gastrectomy had been performed in America for carcinoma The operation was completely successful Some months later when she was apparently in good health, a small solitary nodule appeared in the subcutaneous tissue of the operation scar Soon it began to grow rapidly, but she postponed seeking advice and ultimately died with extensive infiltration of the abdominal wall

Ryall held that, if it could be avoided a doubtful tumour should not be cut into and excised at the same operation The incision wound should be hermetically sealed, or allowed to heal before the healthy tissues surrounding the tumour are excised But if it is absolutely necessary to incise and to remove a malignant growth on the same day, the most elaborate precautions should be taken The exploratory incision must be carefully sutured The skin must be freshly prepared, the surgeon s and the assistants' hands must be sterilized afresh, and every instrument, including the needles, must be boiled once more, soiled towels and sponges must be discarded, and the operation begun anew

Personally, I believe that if a carcinoma is incised it is safer to ablate it at once rather than to wait for the wound to heal The circulatory activity and inflammatory processes of healing must, I think tend to favour rapid dissemination The incision should be packed with a swab dipped in pure carbolic acid and tightly sutured, and the operation of excision should be begun *de novo*, with the precautions detailed by Ryall A pathologist skilled in the interpretation of frozen sections should always be present to make an immediate histological examination when a suspected lump is explored

At the end of every cancer operation, failing any contra indication the wound should be flushed out with a vigorous stream of fluid to wash away any loose cancer-cells I always use 1 in 2,000 perchloride of-mercury solution which will probably coagulate and destroy any isolated cancer-cell which is not washed away

Radium in the prevention of implantation—In any case where it is thought possible that cancer-cells have been set free in the wound during an operation or where complete removal of the growth has proved impracticable, the most effective precaution which can be

taken is to embed in the floor of the wound a sufficient number of radium needles effectively to radiate the suspected area It is, for instance, not rare in operating upon the supraclavicular glands for breast cancer, to find a fixed and irremovable mass at the angle of union of the internal jugular and subclavian veins Such a mass may be transfixed by a radium needle when exposed, but could not be treated effectively by blind methods

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tributary of the fascial plexus and to the little group of papillary vessels which unite to form it. The size of these primary lymphatic areas of the skin I estimate at from $\frac{1}{3}$ to $\frac{1}{4}$ in. in diameter, and there seems to be little communication between adjoining areas except through the medium of the fascial plexus—a fact which explains the nodular character of cancerous invasion of the skin. Both the so-called cutaneous plexuses appear to be illusions. There must, however, be some ground for the fact that these plexuses have been described, and

Fig. 301.—A section vertical to the skin through the edge of an area of Paget's disease. The pattern of the cutaneous lymphatic vessels is emphasized and coarsened by their *distension with malignant cells.*

(Handley's "Genesis of Cancer.")

it would appear that the superficial third of the dermis and the superficial layer of the subcutaneous fat are "planes of confluence"—layers, that is, in which groups of lymphatic vessels are running together to form single vessels. A plexiform appearance is thus produced in these layers, just as the tangle of branches in a wood might lead the observer to imagine that the branches of the trees were united in a plexiform arrangement.

The independence of adjoining lymphatic areas of skin is a fact of great pathological importance. Its full appreciation will, I believe, throw light upon some of the obscurities of cutaneous pathology.

Besides the small tributaries which dip down vertically into the fascial plexus from the surface of the body there are running upwards to the deep aspect of the fascial plexus numerous vessels by means of which it communicates with the lymphatics of the subjacent tissues I have frequently observed such vessels passing to the deep fascia from the muscles and the special liability of some of the subcutaneous areas of the skeleton to cancer appears to show that the fascial plexus anastomoses in a similar way with the periosteal lymphatics wherever they approach the surface

The lymphatics of the breast, though some of them run to the

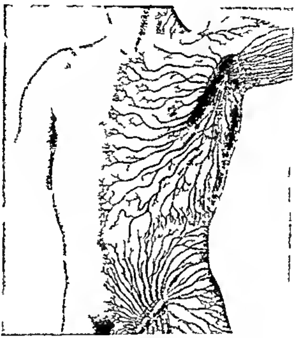

Fig 302 —Trunks of fascial plexus

The fine meshwork of vessels constituting the plexus itself is only partially indicated
(After Sappey's Vaisseaux Lymphatiques)

subareolar plexus and thence to the axillary glands, largely drain into the pectoral plexus that part of the deep fascial lymphatic plexus which lies behind the breast

The fascial lymphatic plexus—The lymphatic plexus of the pectoral fascia is often spoken of as if it were an anatomical entity It is in reality merely a conventional subdivision of the deep fascial lymphatic plexus whose network of intercommunicating channels invests the entire body This plexus (Fig 302) is divisible by the median plane of the body and by two horizontal planes passing through the clavicles and through the umbilicus respectively into six catchment areas three on either side draining as the case may be into the cervical the axillary or the inguinal glands Within each

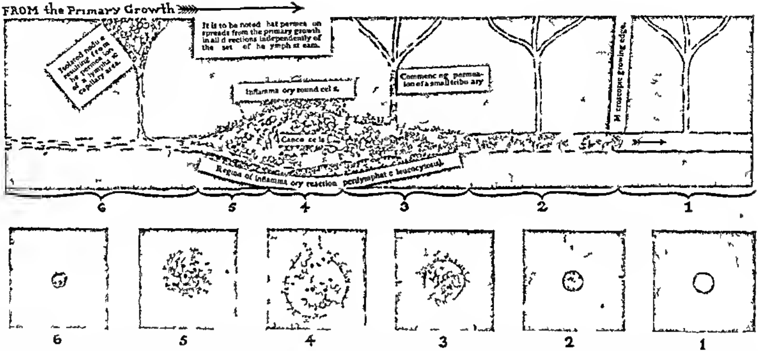

Fig. 303.—Scheme to illustrate advance of permeation along a small lymphatic, seen in the upper figure in longitudinal section and in the lower figures as a series of transverse sections. The lymphatic is finally destroyed by perilymphatic fibrosis. (*Handley's "Cancer of the Breast."*)

1. Normal lymphatic, shortly to be invaded by the advance along it of permeation. 2. The lymphatic permeated by cancer cells but not yet distended. (Note the absence of inflammatory reaction in this region.) 3. The lymphatic distended by the growing cancer-cells; the central cancer-cells are becoming degenerate. 4. The lymphatic ruptured by the growing cancer-cells, an event followed by vigorous inflammatory reaction. 5. The mass of degenerate cancer-cells enclosed in a false capsule of newly formed fibrous tissue. 6. The cancer-cells finally strangled by contraction of their fibrous capsule. The original lymphatic is now represented simply by a thread of fibrous tissue, the cancer-cells having been destroyed.

area a special set of trunk lymphatics arises from the plexus and converges on the corresponding set of glands The line or rather zone, separating any two adjacent areas may be called the lymphatic water parting, and is anatomically a zone of narrow, tortuous channels, nowhere traversed by trunk lymphatics—a region consequently, where the lymph stream is at its feeblest, and where even very fine particles are likely to be arrested The general idea, then, of the parietal lymphatic system is a vast horizontal network of fine channels, co-extensive with the surface of the body, and receiving above numberless fine vertical tributaries, which convey to it the lymph from the skin and its appendages including the breast On its deep aspect the plexus receives tributaries from the subjacent tissues From this great plexus, which lies in the subcutaneous fat upon the deep fascia the lymph is conveyed by six sets of lymphatic trunks, each draining a definite area, to the cervical the axillary, or the inguinal glands

Fig 304 —Infiltration in breast cancer, showing narrow columns of cancer cells growing along the cellular interspaces x 20 (Cf Fig 305)

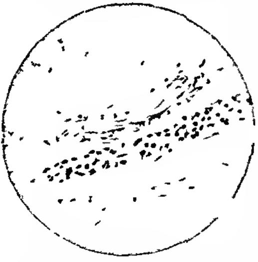

Fig 305.—Permeated lymphatic in longitudinal section. x 50 (Cf Fig 304)
The endothelium of the lymphatic is visible outside the mass of cancer-cells which fills it Above it is seen a normal blood vessel Infiltration of the tissues is absent
(Handley's Cancer of the Breast)

THE PERMEATION THEORY OF DISSEMINATION

Permeation may be defined as the choking up of lymphatic vessels by the growth of cancer-cells along them The lymph stream has nothing to do with it The proliferative power of cancer-cells is so great that when they intrude into a lymphatic channel they advance along it either with or against the stream as a solid plug or growing tendril of cancer-cells (Fig 303) Only in the trunk lymphatics will the intrusive cancer-cells be swept away by the stream to form an embolus in the nearest glands

Some recent writers have used the word "permeation" as synonymous with "infiltration." It will be well, therefore, to state clearly, in tabular form, the differences between those two modes of spread of carcinoma

INFILTRATION (Fig 304)	PERMEATION (Fig 305)
The earliest disseminative process	Begins after infiltration
Best seen at the edge of the primary growth, as defined by the naked eye	Best seen at the *microscopic growing edge*, which, in advanced cases, may be situated in apparently normal tissues, 6 in or more from the apparent edge
The cancer cells are spreading along the tissue interspaces e g between fat cells or between adjoining fibrous bundles	The lymphatic vessels, not the lymphatic spaces, are filled up and choked by solid cords of cancer-cells The tissue interspaces are free from cancer cells
If infiltrating cancer cells intrude into a capillary lymphatic vessel the process of infiltration merges into that of permeation	If a permeated lymphatic ruptures, the cancer-cells set free may infiltrate the surrounding tissues Thus permeation may lead to infiltration
Infiltration is a very slow process because of the resistance offered to the passage of cancer-cells through the cramped and tortuous tissue interspaces	Permeation is a more rapid process than infiltration because the cancer-cells are growing with little resistance along the open lumen of the lymphatic vessels
Infiltration, on account of its slowness is of relative unimportance as a factor in general dissemination	Permeation may carry cancer-cells to a very considerable distance from the primary tumour, and is capable of traversing the minute anastomotic lymphatic plexuses It is accordingly the principal factor in general dissemination

A close analogy exists between the process of permeation and the artificial filling up of the lymphatic channels by an injection fluid such as is used by anatomists to demonstrate the lymphatic vessels If a hollow needle connected with a reservoir containing soluble Prussian-blue solution is plunged into the breast, the fluid will enter the lymphatic vessels near the point of the needle and, after filling up the internal lymphatics of the breast for some distance around the point of injection, will pass backwards along certain lymphatic vessels, first demonstrated by Heidenhain, to the lymphatic network on the great pectoral muscle This pectoral lymphatic plexus is a portion of the great fascial lymphatic plexus, which forms a single network lying on the deep fascia and covering the entire body The injection fluid will spread along this network centrifugally, involving a continually increasing circular area of the fascial plexus The centre of the injected area will always be situated directly beneath the point of introduction of the needle into the breast Its circumference may easily pass far beyond the mammary margin

The fascial lymphatic plexus receives minute tributaries from the muscles beneath and from the skin above At first it will be easier for the fluid to keep in the plane of the main plexus and these little tributaries will escape injection But as the area of the injection circle increases the pressure towards its centre rises with the increasing resistance Some of the fluid will now be forced along the minute tributaries of the fascial plexus and injected areas will appear in the skin and subcutaneous tissues on the one band and in the underlying muscles on the other At the periphery of tbe circle of injection on the contrary the fluid will find it easier to keep along the main plexus rather than to push up the narrow side channels Here accordingly no injection will be seen except in the plane of the main fascial plexus

The fascial plexus is drained by certain trunk lymphatics which pass to the cervical the axillary or the inguinal glands The axillary trunks will soon be filled up by the injection as far as the glands

The spread of cancer of tbe breast or of a cutaneous melanotic sarcoma from the primary growth is exactly analogous to that of an injection fluid save in one respect Any cancer cells which intrude into a trunk lymphatic will be swept by the lymph stream to the axillary glands and the trunk lymphatics themselves will thus be scoured and kept free from cancer-cells Only in a later stage of the disease are the trunk lymphatics choked by permeation

Observations upon which the permeation theory is based—Altbough in 1889 Heidenhain detected lymphatics filled by cancer-cells extending from the breast to the pectoral fascia in two thirds of the cancerous breasts he examined this important observation remained isolated and failed to affect tbe general view of dissemination eveh in the mind of Heidenhain himself M B Schmidt has proved that cancer-cells frequently reacb the blood stream but it appears certain that in nearly all cases these cells are then destroyed for I have shown that the distribution of the secondary deposits is not such as would be expected from this mode of dissemination The evidence cannot bere be fully stated but its salient features are as follows The secondary deposits accessible to observation in breast cancer appear at first near the primary growth and spread from it centrifugally involving a continually increasing circular area of the tissues round the growth but never encroaching upon the distal balf of the limbs the parts whicb upon the embolic theory would appear most liable to metastases The freedom of the distal portion of the limbs applies not only to subcutaneous nodules but also to deposits in the bones

I have endeavoured to elucidate this process of centrifugal spread by cutting long sections of the tissues radiating from a primary growth of the breast into parts of tbe body still unaffected In the proximal portion of the strip—the parts that is to say nearest to the primary growth—I found large isolated nodules of growth Farther out in tissues apparently healthy to the naked eye and perbaps 6 or 8 in from the primary growth I detected what I have described as the *microscopic growing edge* of the disease This edge could be reacbed

in whatever direction the section was orientated from the primary growth itself It forms a narrow zone, a few millimetres wide, in which all the vessels of the lymphatic plexus that receives the drainage of the cancerous organ are choked by cancer-cells The detection of the real microscopic growing edge of a cancer forms the unshakable foundation of the permeation theory The grave difficulty remained that in the region nearer the primary growth no permeated lymphatics could be found This difficulty was solved by the detection of the curative process of *perilymphatic fibrosis* A permeated lymphatic is not a permanent structure The inflammatory reaction excited around the invaded lymphatic by the presence of cancer-cells within it strangles the minute cord of cancer cells, and the original vessel is replaced by a microscopic cord of fibrous tissue (Fig 303)

Here and there, however, the reparative process fails, and at these points within the circle of permeation nodular deposits of cancer form These isolated secondary nodules have really arisen in continuity with the primary growth and in the track of the spreading circle of permeation Their isolation is a secondary phenomenon due to the destruction by perilymphatic fibrosis of the permeated lymphatics which formed the lines of communication.

The permeation theory probably applies to every form of carcinoma, and also to melanotic sarcoma It has been confirmed in breast cancer by Bonney, Rowntree, and others Lenthal Cheatle has observed permeation in carcinoma of the tongue, and I have demonstrated it in cancer of the rectum and of the stomach

Visceral dissemination —A cancer, even if it originates in the superficial structures, such as the skin or breast, often ultimately destroys life by invading the vital organs Sooner or later, it may be after many years, permeation extends from the superficial lymphatics to the subserous lymphatics of the pleura or the peritoneum, an event which soon leads to the escape of cancer-cells into the serous cavities The malignant cells, under the influence of gravity and visceral movement, spread widely in the serous cavity invaded, and implant themselves afresh on the serous surfaces of the viscera, in which cancerous masses appear, and within a few months the patient succumbs A very interesting example of serous invasion followed by this process of transcœlomic implantation is often seen in breast cancer

Epigastric invasion in breast cancer —At the tip of the ensiform cartilage the fascial lymphatic plexus is separated from the subperitoneal lymphatic plexus only by a layer of fibrous tissue, the linea alba, and by loose subserous fat At or near this point, which is situated only an inch from the margin of the breast, breast cancer often directly invades the abdomen The linea alba is infiltrated by cancer-cells from the overlying permeated fascial plexus These cells reach the subserous fat, permeate the subserous lymphatic plexus, and escape into the peritoneal cavity, where they implant themselves on the contiguous convex surface of the liver Other cells are carried by gravity into the pelvis, where they attack the ovaries and the pelvic

peritoneum Thus extensive secondary deposits may form in the abdomen before the thoracic cavity shows any sign of secondary deposit

Invasion of the peritoneum in breast cancer is now much rarer than formerly Removal of the upper part of the anterior layer of the rectus sheath is now a recognized step of the operation for breast cancer, and direct invasion below the ensiform cartilage is thus prevented

Main processes concerned in dissemination.—The processes concerned in dissemination are infiltration, permeation, lymphatic embolism leading to deposits in the lymphatic glands, transcœlomic implantation, and, in exceptional cases, blood dissemination by embolism, or by the growth of solid plugs of cancer-cells along the blood vessels

Infiltration has only a local importance, but permeation, which can extend without let or hindrance throughout the lymph vascular system, is the main factor in dissemination

Blood-dissemination.—Of late, owing to the undue stress laid on blood dissemination in R A Willis's work, "The Spread of Tumours in the Human Body (Churchill, 1934), there has been a certain sway of opinion back to the old embolic theory But Willis, though he was specially looking for evidence of blood-borne metastasis, appears only to have found it in about 36 per cent of his cases There is, of course, no doubt that cancer-cells obtaining access to the blood stream may cause remote secondary deposits There is equally no doubt that many such emboli are destroyed without causing metastasis (Schmidt) Willis draws attention to the small size of many of the embolic secondary nodules he detected, but does not draw the natural inference that *successful* invasion by the blood stream only occurred a short time before death The lateness, and consequent surgical unimportance, of blood dissemination is further shown by the favourable results of operation for breast cancer in really early cases, before invasion of the axillary glands Blood dissemination in carcinoma, though in rare cases it may occur early, is usually an ante-mortem event Otherwise surgical removal would be futile

THE AIM OF THE OPERATION FOR MALIGNANT DISEASE

It has been customary to speak of operations for cancer in terms of the removal of organs Thus the operation for breast cancer is often called an amputation of the breast This looseness of speech encourages unscientific operations It implies, for example, that a single standard operation is applicable to all carcinomata of the breast, in whatever part of the gland they originate Some surgeons who have described modes of operation for breast cancer make no attempt to vary their procedure according to the point of origin of the growth

It is wrong to speak of a cancer operation as an operation for the removal of an organ, because carcinoma spreads from its point of origin centrifugally, with little regard to the boundaries of organs A carcinoma starting on the edge of the breast will soon have spread beyond the limits of the breast on that side If it is treated by an "amputation" rapid local recurrence will take place where the knife, following the outline of the breast, had failed to get beyond the growth

In general terms, the object of a rational operation for carcinoma (and for melanotic sarcoma) *is the removal intact of the permeated area of the lymph-vascular system which surrounds the primary growth, and of the lymphatic glands which have been embolically invaded along the trunk lymphatics of the area concerned*

The surgery of malignant disease is a department of lymphatic surgery, and has nothing to do with the ablational surgery of organs

1 **The operation must be accurately centred upon the primary growth.**—If cancer spreads by centrifugal permeation with approximate equality in all directions, but with a tendency to follow the plane in which the main lymphatic plexus lies, it is essential that the primary growth shall always be the central point of the mass of tissues ablated

2 **The plane requiring the widest removal is that in which the microscopic growing edge is situated**—the plane, that is, in which is situated the lymphatic plexus receiving the lymphatic drainage of the cancerous part

In malignant growths of the superficial tissues, the skin and its appendages (among which the breast is included), the plane of maximal removal is the plane of the deep fascia To make reasonably certain of getting beyond the microscopic growing edge in an average case of breast cancer, I estimate for the removal of a circle of deep fascia 10 or 12 in in diameter, and centred upon the primary growth Since far less skin needs removal, the skin flaps must be extensively undermined

3 **Planes adjacent to the plane of the main lymphatic plexus require to be ablated over a certain area concentrically with the growth *but less widely* than the plane of the growing edge.**—The planes to be considered are (*a*) the skin and subcutaneous fat, (*b*) the muscles underlying the deep fascia The reason they are infected is that their lymphatics drain into, or communicate with, the fascial lymphatic plexus, from which permeation extends to them The reason they are invaded over an area smaller than the circle of the growing edge in the deep fascia is that the cancer-cells for some time find it easier to proliferate in the meshes of the main plexus than to fill up the narrow side-tracks which run into it

(*a*) **Ablation of skin**—When cancer nodules appear in the skin near a breast cancer, they spread centrifugally away from the primary growth This has been erroneously taken to prove that the disease spreads in the plane of the skin In this belief some operators have sacrificed such extensive areas of skin that they have to resort

habitually to skin grafting The curious thing was that skin nodules continued to appear beyond the extensive area of skin removed The attention concentrated upon the skin was diverted from the deep fascia in which the unrecognized microscopic growing edge lay concealed ready to effloresce later in the form of skin nodules as permeation extended to the skin at isolated points

In breast cancer I have shown conclusively that removal of a circle of skin 4 or 5 in in diameter centred upon the primary growth is sufficient in nearly all cases to prevent recurrent skin nodules *provided that the microscopic growing edge is ablated* by a wide removal of the deep fascia This conclusion arrived at by histological work in the laboratory has been amply confirmed by clinical experience The history of this subject is an excellent example of the value of pathological research in checking operative excesses

(*b*) **Removal of muscle**—The need to remove a layer of muscle subjacent to the primary growth depends on the extension of permeation from the fascial lymphatic plexus into its muscular tributaries As far as possible the layer of muscle removed should attain its maximum thickness just beneath the primary growth and should become thinner towards the periphery of the operation area But for several reasons ablation of muscle cannot be carried out in the same strict conformity with the law of centrifugal spread as is possible and desirable with the skin and deep fascia For in the first place once a muscle is invaded by cancer its contractions probably lead to a wide dispersion of cancer cells in the direction of its fibres between the muscular bundles so that the whole muscle must be regarded as suspect In the second place it is useless to scoop out a circular portion of muscle on the centrifugal principle because the remaining portions will be functionally useless and may become a cicatrix hampering the movements of adjacent joints

The present practice in removing muscles appears to be correct In breast cancer originating in the upper part of the breast the whole of the great pectoral and in other cases the whole of the muscle except its clavicular fibres should be removed as Halsted recommends The removal of this muscle is essential not only on account of its close relations with the breast but also in order to reach the apex of the axilla The minor pectoral which is in direct contact with the breast along its lower border should also be taken away Furthermore it is important to remove a layer of the digitations of the serratus magnus which lie in direct contact with the deep surface of the breast This point has I believe been overlooked A superficial layer at any rate of the digitations of the external oblique which arise from the 5th and 6th ribs requires removal for a similar reason

An outstanding service of Halsted to breast surgery is that in every case he insisted on the removal of the sternal portion of the great pectoral This step found many opponents who asserted that it produced serious disability As late as 1909 the weight of French surgical opinion was opposed to ablation of the pectoral. As a matter

of fact, if the after-treatment is properly conducted, the disability is negligible

Speese has ended controversy by a paper recording the examination of the great pectoral in **100** consecutive cases The muscle, or the pectoral fascia in contact with it, showed cancer in 87 cases In 5 cases in which the growth was free from adhesion to the muscle there were, nevertheless, metastases in the muscle

General considerations in the removal of lymphatic glands.—The systematic removal of possibly infected lymphatic glands is imperative in all malignant tumours, except those which are definitely known not to disseminate by the lymphatic system The exceptions include rodent ulcer, many of the less malignant sarcomata, and carcinomata arising at points where the lymphatic system has previously been destroyed by a lymphangitis Of the last class, epithelioma arising on a scarred area of lupus may be taken as a type

It has been commonly believed that the sarcomata do not disseminate by the lymphatic system I have proved that this is quite erroneous in melanotic sarcoma it is probably untrue of many other sarcomata Therefore, except in the fibro sarcomata removal of the glands should be the rule It should never be omitted in sarcoma of the tongue, the testis or the tonsil, in periosteal sarcoma or in sarcoma of the breast

In general terms the glands requiring removal are those which receive the lymphatic vessels of the area where the malignant growth arises The task is not so simple as it seems In the first place, afferent lymphatics may pass by the first set of glands they reach and may run directly to the set above Thus, lymphatic vessels often run directly from the breast to the highest axillary glands and these may be cancerous when the lower axillary glands are still free Again, in the tongue, as Jamieson and Dobson have shown, some of the lymphatic vessels may pass directly to the lower deep cervical glands instead of entering the upper deep cervical glands Moreover, every infected gland is itself a centre of infection for the glands farther off It is true that for a long time a gland filters off the cancer-cells which reach it, but sooner or later the growth permeates to its efferent lymphatics which are afferent to the glands higher up In this way the supraclavicular glands are often reached in breast cancer, or the iliac glands when there are secondary inguinal glands

It must not be forgotten that in its early stages gland infection is a microscopic and clinically inappreciable process Accordingly, the fact that no enlarged glands can be felt does not absolve the surgeon from the duty of performing a complete gland dissection if the growth is one which habitually disseminates by lymphatic channels Only in very old and feeble patients can a relaxation of this rule be allowed, and its neglect is a frequent cause of failure

A primary growth may, by infiltration or permeation, reach an area which has a different lymphatic drainage from the area in which it originated Hence a knowledge of the respective catchment areas of

the different sets of lymphatic glands is very important Thus in a late stage of breast cancer, when the disease has permeated across the middle line the opposite axillary glands receive cancerous emboli along their trunk lymphatics Their enlargement indicates that permeation has crossed the middle line into their catchment area

If a growth originates in or near the middle line, two sets of glands will require removal the glands of the two contiguous areas concerned

Fig 306—Rodent ulcer before excision

If a growth originates at the level of the umbilicus some way from the middle line both the axillary and the inguinal glands on that side must be removed If a growth originates at the umbilicus itself then if possible four sets of glands should be excised—those in both axillæ and both groins

If a growth originates just above the level of the umbilicus away from the middle line removal of the axillary glands on the affected side will suffice if the growth is early, but if it has already infiltrated or permeated down to the level of the umbilicus, then in addition the inguinal glands of the affected side must be removed

Decussation of lymphatics—Gland removal is complicated by the fact that lymphatic trunks originating on one side of the body may be afferent to glands situated on the opposite side The decussation of lymphatic trunks across the middle line is especially rich in the tongue, and Jamieson and Dobson have shown that the only portion of the tongue which discharges exclusively into glands of the same side is the posterior two thirds of the lateral margin Accordingly only in cancer of the lateral margin of the tongue is it reasonably safe to restrict gland removal to the glands of the same side

Comitance of lymphatics and blood-vessels—Lymphatics and blood

Fig 307 —Same case as Fig 306 after excision

vessels run in parallel and closely contiguous courses Each small artery and vein is usually accompanied by two lymphatic vessels If the latter become permeated their rupture may be followed by infiltration of the wall of the comitant vein The growth may thus in a late stage obtain access to the blood stream as I have demonstrated in melanotic sarcoma

It is difficult to pursue the subject of this chapter into detail without trenching upon the province of those who have dealt with the surgery of cancer of the various organs There are, however, two varieties of malignant growth which have no definite anatomical location On that account they are usually passed over in works on operative surgery, and, as a natural sequence, their operative treatment is oft

Fig 308 —Very advanced rodent ulcer

Beginning just in front of the ear the ulcer has destroyed the pinna, covered the external auditory meatus, and infiltrated the bones of the skull especially the temporal bone which was exposed in the floor of the ulcer. Protracted X-ray treatment had proved useless.

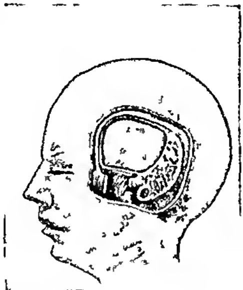

Fig 309 —After block removal of ulcer and subjacent infiltrated bone

The dura mater is freely exposed in the squamous region of the temporal bone. The bone removal extends to the mastoid region and cuts across the bony meatus and the temporo-mandibular joint. *The zygoma has gone, and most of the temporal* muscle. The external pterygoid and a few divided fibres of the temporal muscle are seen. The condition of the patient did not admit of a plastic operation or skin grafting.

Fig 310 —Later stage

The wound has epithelialized completely. The dura mater could still be seen pulsating under its thin covering of skin. The patient's general condition was greatly improved.

very inadequate These are rodent ulcer and melanotic sarcoma of the skin Their consideration will illustrate the principles governing the operative treatment of (1) a malignant growth which has no tendency to disseminate, (2) a malignant growth which disseminates by permeation of the lymphatic system

(1) Operative Treatment of Rodent Ulcer

Rodent carcinoma or rodent ulcer, presents certain peculiarities which place it, as regards treatment, in a class apart from most

Fig 311 —Advanced case of rodent ulcer treated unsuccessfully by radiation

The eye had been destroyed, and the growth extend d back into the orbit The dotted line indicates the skin incision The two following figures show the operation.

malignant tumours Chief among these peculiarities is the fact that it does not disseminate, and that consequently ablation of the primary tumour is the surgeon's sole object This alone, however, is often a business demanding all his resolution, for he is frequently called upon to operate in a late stage, either because the patient has not previously sought treatment or because attempts to cure the disease by radium or X-rays have been too long maintained

The choice between radiation and operation.—While some rodent ulcers yield rapidly and completely either to X-rays or radium,

others prove refractory or relapse after a period of apparent cure and there is no means of telling beforehand which of these events will happen To counterbalance its uncertainty treatment by radiation possesses the advantages that it avoids an operation and that the scar is often inconspicuous In my opinion operation should be preferred to or substituted for radiation in the following classes of rodent ulcer

(a) *Where the disease is a small incipient plaque in which ulceration*

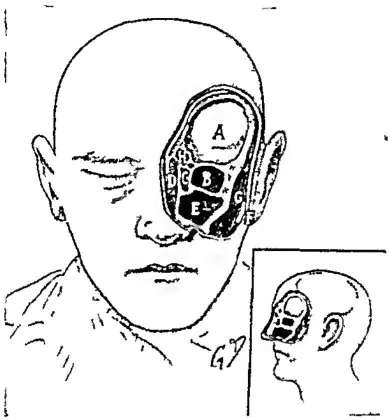

Fig 312 —Same case as Fig 311, after block removal of affected parts, including portion of frontal nasal lacrymal, and ethmoid bones and superior maxilla.

A Frontal dura mater B Remains of orbit C Ethmoidal cells D Intact mucosa of nasal cavity E Maxillary antrum F Zygoma G Temporal muscle The inset figure shows the scalp-flap which was utilized to fill up the facial gap

has hardly begun —The operation is a trivial affair leaving a small linear scar It is true that in most cases the application of radium for a few hours will produce complete cure but the dread of local recurrence is more absolutely excluded by operation Radium treatment is preferable if the growth is near the eye Many surgeons and most radiologists prefer radium to operation for all cases of this class and within a few years as radium methods become standardized their views may prevail

(b) *Where the disease has recurred after apparently complete cure by*

radiation —An exception may perhaps be made in those cases where an operation involves serious disability or an especially disfiguring scar but in the surgery of malignant disease an ugly scar or the loss of an eye may be the price of success

(c) *Where the disease remains active at the end of three months from the time radiation treatment began* —The type of rodent ulcer which responds sluggishly to radium or X rays appears to be especially liable to relapse even if complete cicatrization is at length obtained

(d) *In cases where the ulcer has exposed a bone has attacked cartilage or the conjunctiva or has eaten deeply into soft tissues* —Rarely if ever

Fig 313 —Same case as Fig 311 after healing had taken place

is radiation successful when once the disease has attacked a bone or has affected the conjunctiva

The failure of radiotherapy to deal with rodent ulcer of the conjunctiva may be ascribed to several causes The dosage is restricted by consideration for the safety of the eye The conjunctiva is closely related to the lacrymal bone and the anterior ethmoidal cells If the disease attacks the conjunctiva near the inner canthus the usual event the disease probably attacks the ethmoid at about the same time In this bone it spreads rapidly and secretly extending far back along the inner wall of the orbit without giving external manifestations of its presence In such a case removal of the eye is a necessary preliminary

to treatment of the ethmoidal extension of the disease and the orbital fat after removal is often found to be infected

Principles of operative treatment—Rodent ulcer is one of the few forms of malignant growth where the primitive method of cancer surgery—the cutting out of the primary lump with a margin of healthy tissue—is still the method of choice Every infirmary contains an example of the dreadful ultimate fate of some of the victims of this disease—the conversion of the face into a gaping chasm The remembrance of such cases brings the conviction that even when operation involves the sacrifice of an eye or the removal of part of the frontal bone the nasal bones or the maxilla the patient should be earnestly advised to submit to the ordeal

The method in these advanced cases is brutally simple and it may be described as a block dissection including bone remorselessly pursued without regard to anatomical considerations It is not generally realized how safely wide ablations of this kind can be made in face and forehead Many cases of rodent ulcer are labelled inoperable which could be cured or relieved for some years by bold operative measures The ulcer is surrounded at a distance of not less than ½ in from its margin by a ring incision which extends down to the bone Into this incision a chisel is introduced and with a mallet a similar annular groove is cut in the underlying bone or bones The chisel as in a recent case of my own may perhaps have to traverse the floor of the orbit the nasal bones the superior maxilla and the malar bones It is now introduced beneath the mass thus outlined which by a combination of mallet blows and judicious leverage is separated from its deep connections It is very undesirable to open up the nasal cavity the mouth or the frontal sinus if this can be avoided Even when the overlying bones are involved if care be exercised they can be stripped from the underlying mucosa without injury to the latter If the whole thickness of the frontal bone has to be removed special care should be taken to avoid septic infection of the exposed dura mater

Hæmorrhage may be troublesome but the parts are so freely exposed that it is unlikely to be dangerous If after tying off spurting vessels there is still persistent free oozing the cavity may be packed with gauze wrung out of 1 in 1 000 flavine and the plastic part of the operation deferred In cases where the nasal cavity may be opened during the operation the nostril on the affected side should be previously plugged with gauze

Plastic repair of the gap—By the use of scalp or neck flaps combined if necessary with transplantation of costal cartilage the majority of extensive gaps in the face can be satisfactorily repaired In this respect war experience will in the future come to the aid of civil surgery Even if the strain of an extensive plastic operation cannot be borne it is surprising how much natural cicatrization will reduce the size and unsightliness of the defect

Illustrative case—The patient aged about 55 had for sixteen years

suffered from a rodent ulcer of the right side of the face It began near the inner canthus, and at the time he came under observation it formed an irregular ulcer involving most of the right side of the face, and exposing and infiltrating the right superior maxilla above its alveolar border, the right nasal, lacrymal, and inferior turbinate bones (Fig 806) The eye was shrunken and destroyed, the growth had destroyed the lower eyelid, and was infiltrating the inner part of the upper one The ulceration extended over the middle line of the nose nearly to the left naso facial sulcus The right nostril was entirely destroyed Below the growth extended to within ½ in of the free margin of the upper lip but it did not involve the mucosa of the mouth nor extend to the alveolar border It was thus possible to operate without opening up the oral cavity Externally, the growth extended to the outer part of the malar eminence

The operation was simple in principle and did not take any nice regard of anatomical structures of secondary importance The growth was surrounded at a safe distance by an annular incision down to the bone The chisel was then applied to the bones at the bottom of this incision and a block of the bony tissues of the face was removed along with the superjacent growth and the shrunken eyeball and fatty contents of the orbit The ablated mass contained most of the maxilla, without its alveolar border and posterior margin a portion of the right malar, ethmoid, and inferior turbinate bones the right lacrymal both nasal bones and portions of the nasal cartilages Bleeding was troublesome

The cavity left after removal of the mass presented at the bottom a circular bony cell, the posterior third of the antrum of Highmore On the inner side was the nasal septum, and above was the posterior part of the orbit The lacrymal gland was included in the excised tissue

A large flap with a pedicle below was now marked out on the side of the cranium, was raised from the epicranial aponeurosis and brought forward to cover the gaping chasm The denuded area of scalp was at once grafted from the skin of the thigh The patient seemed little the worse for this severe operation and made a rapid and apyrexial recovery, *with very great improvement in his general health and* appearance (Fig 807)

In 1921 (three years after the operation) the disease recurred about the right nostril, in the region where the operation was restricted in order to avoid opening the mouth cavity Here a tube of radium was buried, and the disease was again checked In 1922 the growth was spreading back within the right side of the nose The patient was subsequently lost sight of The lesson of the case is that radical operation should not be postponed too long

The place of plastic surgery in the treatment of malignant disease — An operation for a malignant tumour has two stages (1) the ablation of the diseased tissue with all its microscopic extensions, (2) the repair of the defect thus created

Some surgeons have been led to adopt methods in which the first of these objects is sacrificed to the brilliant attainment of the second with necessarily unsatisfactory results. The removal of the cancer must be the operator's sole concern in the early stage of the operation (Figs 314, 315.) Only when this has been done must he begin to think how the resulting gap is to be closed (Figs 316, 317.) If the flaps cannot be brought together, simple skin grafting is usually the best resource. In exceptional cases, especially in the face and scalp, a

Fig 314.—Case of rodent ulcer of many years' standing

The frontal bone was exposed and infiltrated in the floor of the ulcer, which had continued to progress in spite of persistent X-ray treatment. Before the patient came under the writer's care, operation had been refused, the case being regarded as hopeless. The dotted line indicates the skin incision.

plastic operation by a pedicled flap may be desirable, though rarely essential.

Rodman, in condemning plastic procedures in breast surgery after ten years' experience, states that they secure easy primary coaptation at the expense of an abiding result, and this appears to be a fair judgment. He adds: "They are inadequate, disappointing, and do not meet the pathological requirements necessary in dealing with an infiltrating and disseminated malignant process. The primary defect with all of them is that they subordinate a radical cure to the carrying out of a preconceived plan which will do very well *in some cases* when the lesion is favourably situated, but will fail in many, perhaps most, in

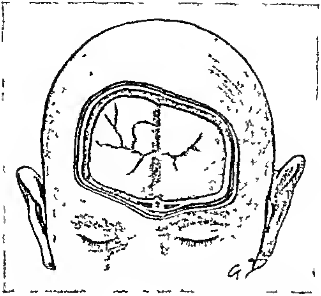

Fig 315 —Same case, showing extent of frontal bone removed in one piece with the ulcer, together with margin of surrounding healthy scalp

The dura mater is exposed in the floor of the wound Below, the frontal sinuses have been cut across

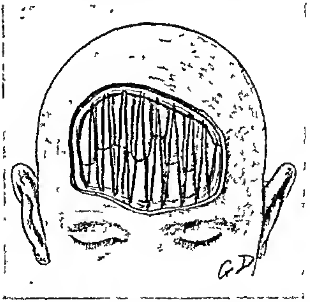

Fig. 316 —Same case, showing gap in frontal bone filled up by shavings of costal cartilage, held in position by catgut interlacement gripping edges of periosteum.

stances where they are practised I cannot doubt that he who employs them will find himself sooner or later the victim of shattered hopes and definitely put them on one side as alluring and convenient for the surgeon but an enormous handicap to the patient This condemnation appears to be none too strong

One of the most attractive of the plastic operations for breast cancer is the method of Tansini in which a large flap cut from the scapular region with its pedicle near the edge of the latissimus dorsi is brought forward to fill up the gap To ensure the vitality of this flap the deep fascia at the edge of the latissimus must be preserved But if this is

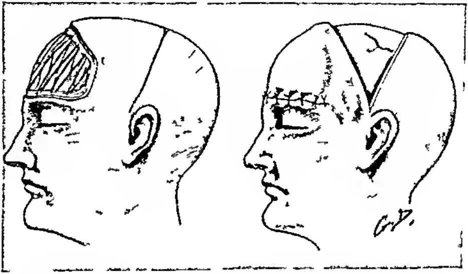

Fig 317 —Same case showing closure of frontal gap by bridge flap

The flap is first defined posteriorly by an incision crossing the vertex of the skull from ear to ear next loosened from its deep connections, leaving the periosteum only to cover the bone and then pushed forwards over the frontal region Its anterior edge is sutured to the lower edge of the frontal skin incision The bare area of periosteum left at the summit of the skull is covered with skin-grafts taken from the thigh The whole operation was performed at one sitting, and healing was complete within a fortnight The patient remained well for over three years but ultimately died of recurrence

done it is very probable that a portion of the permeated area of the deep fascia near the base of the flap will be left intact to reproduce the disease

Closely related to the fallacies of plastic surgery are ill advised attempts to preserve structures lying in close relation to a malignant growth simply because they are of great functional importance Examples of this are seen in attempts to preserve the eye when a rodent ulcer has already attacked its conjunctiva In rectal carcinoma attempts to preserve the anal function by leaving behind the anus and its muscles generally end in recurrence in these structures Only in growths which do not tend to disseminate do plastic procedure as a rule commend themselves

(2) Operative Treatment of Melanotic Sarcoma

Ribbert has shown conclusively, I think, that these tumours are never carcinomatous, though some pathologists are still inclined to believe in their epithelial origin

Mode of spread of melanotic sarcoma—It may be fairly presumed that a primary melanotic sarcoma spreads from its point of origin in the same way as the disease is known to spread from a secondarily infected gland That is to say, sarcoma cells obtain access to the small lymphatics which run from the skin to the deep fascial plexus Permeation extends along them, and an area of the deep fascial plexus immediately beneath the growth becomes choked by sarcoma cells The circle of permeation now spreads with greater readiness in the deep fascial plexus, involving a circular area of this plexus with the primary growth at its centre In operating the essential point, to prevent local recurrence, is therefore to remove a considerable circular area

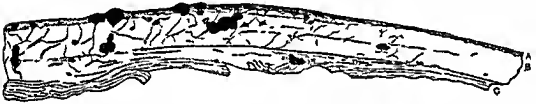

Fig 318—Drawing $\frac{2}{3}$ natural size of translucent strip of skin and underlying tissues taken in a radial direction from a focus of melanotic growth in the inguinal glands to demonstrate centrifugal spread of permeation Note that the growth extends much farther along the deep fascia than along the skin or in the muscle

Handley's Cancer of the Breast

A Skin B Subcutaneous fat separated by the deep fascia from C a thin layer of muscle D Margin of mass of growth in the situation of the inguinal glands

of the deep fascia round the primary growth After a time just as in breast cancer, the small tributary lymphatics which run into the permeated area are themselves permeated This necessitates the removal of a smaller circular area of the muscles beneath it and of the skin over it (Fig 318)

The question now arises whether the trunk lymphatics running from the primary growth to the glands should be removed Although for a long time the lymph stream clears them and keeps them free from infection, there can be no doubt that the ideal plan is to excise the trunk lymphatics in continuity with the primary growth and the glands Sometimes this is troublesome, on account of the great distance between the growth and the glands, but I have excised a bridge of deep fascia extending from the base of a finger up to the axilla

Removal of the lymphatic glands—Writing in 1902, Eve said "The removal of the nearest chain of lymphatic glands, whether palpably enlarged or not, should never be omitted, for it may be taken as a matter of certainty that in a great majority of cases they

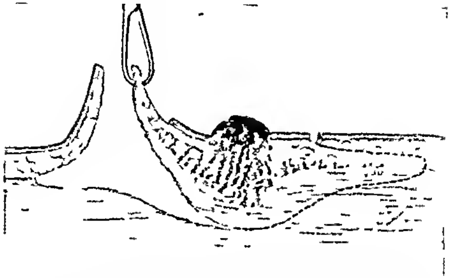

Fig 321 —Undermining of skin flaps has been completed

A circle of deep fascia, 4 5 in in diameter has been exposed, and has been circumscribed by a ring incision down to the muscles leaving however a bridge of fascia 1 in wide where the trunk lymphatics pass out towards the glands This bridge is not represented. The operator now proceeds to raise up a thin fringe of deep fascia from the underlying muscle all round for about 1 in He next begins to scoop out as he approaches the region of the tumour a layer of the subjacent presumably infected muscle The thickness of this layer reaches its maximum at the centre of the field of operation.

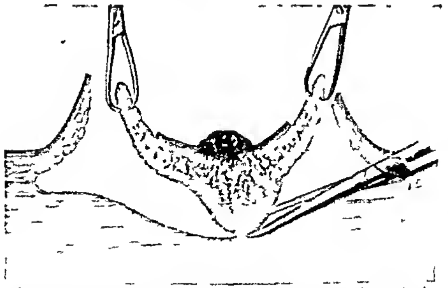

Fig 322 —Process of cutting out infected area of muscle is nearly completed

The excised primary growth remains attached only by the undivided bridge of deep fascia (not shown) which attaches it to the trunk lymphatics A linear incision is now made along these lymphatics as far as the glands of which they are tributaries. First the bridge of fascia carrying the trunk lymphatics, and next the glands themselves, are to be excised The specimen removed is in one piece with the primary tumour at one end the glands at the other and an intervening length of fascia

thin attached layer of subcutaneous fat, is now separated from the deeper structures for about 2 in in all directions round the skin incision At the extreme base of the skin flaps a ring incision down to the muscles surrounds and isolates the area of deep fascia and overlying deeper subcutaneous fat to be removed (Fig 321) This ring incision, however, is not a complete circle On the proximal side, where the trunk lymphatics leave the infected area of deep fascia, a bridge of deep fascia perhaps 2 in wide is left The isolated fascial area is now dissected up from the muscles beneath, to a line which corresponds with the circular skin incision Finally, the mass of isolated tissues, with the growth at its centre, is freed by scooping out with a knife a circular area of the muscle immediately subjacent to the growth It remains attached only by the undivided bridge of deep fascia which carries the trunk lymphatics of the affected area (Fig 322)

Removal of the trunk lymphatics —A linear skin incision is now made along the length of the limb, starting from the upper end of the existing skin incision and extending to a point directly over the first set of lymphatic glands The skin is reflected for 1 in on either side, exposing a band of deep fascia 2 in wide connecting the primary growth with the glands Starting below, where the primary growth remains attached to it, this band of deep fascia is dissected up from the subjacent muscles until the region of the glands is reached Its connections above with the gland must not be severed, but the skin incision may be conveniently sutured nearly to its upper end

Removal of the glands —The incision is now extended over the region of the glands In the axilla a linear incision suffices, and in the groin is preferable to a T shaped incision with the transverse limb following the line of Poupart's ligament The latter incision is apt to be followed by sloughing of ill-nourished skin Skin-flaps are reflected some little way, as over the primary tumour, in order to excise a certain area of the surrounding deep fascia along with the glands An edge of deep fascia is raised up all round, and the mass of glands is then dissected away It comes away still connected by a long bridge of deep fascia with the primary growth

Removal of the next higher set of glands —To make the operation an ideal one, it is necessary, in the lower limb, to remove the glands along the external iliac artery which, though unenlarged, are probably infected microscopically In a case operated upon some years ago, though no gland could be felt above Poupart's ligament, a black, enlarged gland was found at operation upon the outer side of the external iliac artery In the same case the microscope showed permeated lymphatics in the ablated area of fascia excised along with the inguinal glands Similarly, in the upper limb the supra-clavicular glands should be removed These procedures should be carried out through separate incisions, and may often be best deferred to another occasion if the operation has already taxed the patient's stamina

gation of the first incision into its fornix, and was completely cleared of its fat and glands The supraclavicular glands were then removed through a separate incision The patient made a good recovery About a year later a recurrent nodule appeared over the lower part of the triceps at the back of the arm It was excised on December 15th, 1909, and, on section, was found to be a typical sarcoma, unpigmented and degenerate at the centre (It is well known that unpigmented metastases are not rare in melanotic sarcoma,) This patient died in 1930 of an independent disease and without recurrence of the melanotic growth

For many years I believed that this was the first case of melanotic sarcoma to be treated on scientific lines I was wrong The late Mr J Hogarth Pringle of Glasgow as early as 1898 had begun to operate on precisely similar lines His operation was based upon the clinical observation that in melanotic sarcoma nodules may appear along the line of the trunk lymphatics intervening between the primary growth and the regional lymphatic glands

Mr Pringle,* in describing two cases upon which he had operated, wrote " A radical extirpation of this disease will most certainly be ensured by excision of the tumour with a good zone of healthy skin around it, and a somewhat larger zone of the underlying subcutaneous tissue and deep fascia, along with a broad strip of subcutaneous fascia up to and including the nearest anatomical group of glands at least, and all that is removed should be in one continuous strip "

In the *Lancet*† Mr Pringle was able to record that both these cases operated upon respectively in 1898 and 1900 the only ones of melanotic sarcoma upon which he had operated still remained well in 1937, though the glands showed secondary deposits at the time of operation in both Mr Pringle's clinical acumen anticipated the results of my pathological researches of 1907 08, and he was the pioneer of the adequate treatment of this disease

By way of contrast I may briefly record here a case which came under my notice recently An enlarging mole was removed under local anæsthesia by the patient s practitioner from the back of the neck on the left side Shortly afterwards a gland appeared in the posterior triangle It was removed under a local anæsthetic A second gland appeared almost at once and was removed under a general anæsthetic When I first saw the patient a few months later, a fixed dusky induration occupied the whole supraclavicular region and dullness at the base of the homolateral lung indicated extensive secondary deposits in the pleura

DIATHERMY IN MALIGNANT GROWTHS

If a high voltage alternating current is passed through the tissues of the body, they become heated in the same way that a wire is heated by the passage of a current through it The heat is produced in the

* *Edin Med Journ.*, June 1908 N.S xxiii, 498
† Feb 27 1937 i 509.

Operation for melanotic sarcoma of the face.—The monobloc type of operation described is specially difficult in melanotic sarcoma of the face, but it is feasible. In a recent case of melanotic sarcoma of the middle of the cheek, recurrent after an inadequate operation, in a young man, no enlarged glands could be felt, but exploration showed black glands beneath the parotid fascia and along the main deep cervical chain. The portion of tissue removed in one piece by a troublesome dissection included the primary growth with a margin of skin and fascia, a band of fascia passing across the cheek and over the parotid gland, and all the glands of the main chain from the base of the skull to the sterno-clavicular joint. Facial paresis resulted, but was not ultimately very noticeable. The patient remained free from recurrence for nearly two years after the operation,* but then developed signs of general melanosis, probably due to blood-dissemination. It is of special importance to notice the absence of any clinical evidence of infection of the glands.

Prognosis after operation.—Melanotic sarcoma is generally regarded as one of the most deadly and hopeless of malignant growths. My impression is that this evil reputation springs less from the inherent malignancy of the disease than from haphazard and unscientific methods of operative treatment.

On account of its rarity, no individual can collect statistics of results. I may, however, briefly record a case in which the foregoing principles were successfully applied, although when first seen the growth was recurrent and the axilla was full of malignant glands.

Illustrative case.—Miss C., aged 40, sent to me by Dr. Burstal, of Staines, on October 21st, 1909. In September, 1907, Dr. Moreton Palmer removed an ulcerated papilloma which had been present on the dorsum of the left wrist for three or four years. In September, 1908, some small lumps were removed just above the epitrochlear gland. These lumps were subcutaneous and not glandular. A week or two later a small dark nodule appeared just below the incision. It was removed under local anæsthesia, and was reported as a malignant melanoma. Subsequently the patient suffered much pain in the bicipital region, thought to be due to an involvement of nerves in the scar. On examination I found a vague induration running up the axillary vessels about the middle of the upper arm, midway between the axilla and the scar of the second operation, and it appeared probable that the growth was recurrent. Moreover, a large gland, nearly as big as a chestnut, could be felt in the axilla. I therefore advised a thorough operation which should include removal of the supraclavicular glands, clearing the axilla, and excision of the deep fascia, extending from the axilla almost to the elbow. The patient consented to the operation, and was admitted to the Bolingbroke Hospital. A semilunar flap of skin, involving most of the inner aspect of the arm, was turned back, and the deep fascia was widely removed, with exposure of the brachial vessels and accompanying nerves. The axilla was opened by a prolon-

* The case is illustrated in "Postgraduate Surgery," by Rodney Maingot, Vol. III.

gation of the first incision into its fornix, and was completely cleared of its fat and glands. The supraclavicular glands were then removed through a separate incision. The patient made a good recovery. About a year later a recurrent nodule appeared over the lower part of the triceps at the back of the arm. It was excised on December 15th, 1909, and, on section, was found to be a typical sarcoma, unpigmented and degenerate at the centre. (It is well known that unpigmented metastases are not rare in melanotic sarcoma.) This patient died in 1930 of an independent disease, and without recurrence of the melanotic growth.

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DIATHERMY IN MALIGNANT GROWTHS

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tissues not conveyed to them from a heated electrode, as in the ordinary electro-cautery The effect produced varies from a pleasant warmth to unbearable heat and coagulation of the tissues Their contained water boils and comes off as steam and a desiccated eschar is left

Two dissimilar electrodes are used in surgical diathermy in which a cauterizing action is desired A large neutral electrode consisting of a metal plate covered with lint soaked in strong salt solution (10 per cent) is placed behind the loins The skin may be burned if this electrode is too small if it does not make proper contact with the skin over its whole area or if a fluid of high electric resistance such as water or *weak* salt solution is used to moisten the pad The active electrode is a needle in an insulated handle

Operation by diathermy—The replacement of the scalpel by the diathermy needle as a cutting agent though attended by great technical advantages presents certain countervailing risks Those who have not seen the method in use and have not had considerable practical experience of diathermy for smaller operations will be well advised to adhere to the scalpel for large operations such as that for carcinoma of the breast

Choice of apparatus —Many forms of diathermy apparatus quite satisfactory for medical purposes are useless to the surgeon because they are deficient in the essential quality—rapidity of cutting with minimal cauterization effect The best American machines such as the Wappler are practically unavailable in this country for lack of agency and service A good alternating current machine is supplied by Schall or by the General Radiological Company Since new models of English make are now being introduced the best advice that can be given is to make trial of different machines for actual operations and to purchase the one which cuts most easily and leaves an uncharred surface

The active cutting electrode is a blunt needle well insulated in a non conducting handle The current is controlled by a foot switch or better by a technician in attendance The electrode is sometimes *made in the form of a knife but the simple needle is better because* it secures a maximum concentration of the current at one point rather than its diffusion over a surface or edge Rapid cutting is thus facilitated Since it is the spark rather than the needle which is the cutting agent little resistance is felt when the instrument is working properly The tissues melt away before the needle which should be employed delicately with light rapid strokes Prolonged contact of the needle at any one point is certain to produce a slough and to imperil primary union

The diathermy needle may be employed for two distinct purposes—either to coagulate and destroy a mass of tissue *in situ* leaving it to be separated later as a slough by the natural processes or as a substitute for the scalpel to cut out and remove an area of tissue

When the first edition of this book was published diathermy used in one or other of these two modes had largely replaced the knife in the treatment of cancers of the oral cavity If an oral growth has to be excised diathermy remains the best method But in this field diathermy is now seldom employed because radiation by radium gives better results with less deformity and disablement

On the other hand the scope of diathermy has been greatly extended in dealing with those malignant growths in which radiation treatment has not yet replaced operative removal as the method of choice This remark applies especially to breast cancer but also to cancer of the rectum and in my hands more recently to cancer of the stomach

Advantages of diathermy Loss of blood minimized —As contrasted with the scalpel the diathermy needle possesses various advantages It seals off all the smaller vessels in the plane of section which often remains perfectly dry Thus the loss of blood is reduced to a minimum Any artery which bleeds is seized with forceps and may be subsequently tied If the artery is a small one it suffices to touch the forceps hanging from it (held up out of contact with the rest of the tissues) for two or three seconds with the terminal Charring and bubbling occur at the point of the forceps which may then be removed This method is unsafe for vessels of any considerable size but it saves time for the smaller vessels It should not be used for vessels on a thin flap as the overheating of such a flap may lead to sloughing

Avoidance of shock —Perhaps the greatest advantage of diathermy is that it appears to divide nerves without stimulating them and thus without causing shock In gastrectomy the absence of shock after division of the stomach by diathermy is strikingly brought out by the maintenance of a nearly normal pulse rate through the operation and during convalescence It is certain that diathermy does not stimulate the motor nerves though faradic undertones of the current may occasionally cause muscular contraction A similar indifference to the diathermic current may be postulated for the sensory nerves The pain of surgical diathermy is apparently not due to division of the nerves but to the heating of the adjoining tissue

Elimination of chill local and general —Most extensive operations necessitate prolonged exposure of tissue surfaces and consequent loss of body heat By eliminating chill the diathermic method removes one source of shock The whole cone of tissue intervening between the large neutral electrode and the cutting point has its temperature raised the heating effect is thus a systemic as well as a local one In operations on the breast which involve the cutting of long badly nourished flaps especially liable to chill and the exposure of a large area of chest wall denuded of muscle this effect of diathermy is especially important

Avoidance of implantation —In cancer surgery diathermy minimizes the risk of the implantation of cancer-cells on the wound If the scalpel happens to cut across a group of cancer-cells viable cells are

set free in the wound The diathermy needle destroys a microscopic layer of cells on either side of its plane of section, sterilizing the wound as it goes

Any lymphatic vessels cut by the diathermy needle will be sealed off

Dangers and disadvantages of diathermy. Risk of explosion — No anæsthetic whose vapour forms an explosive mixture with air may be used during diathermy Serious and even fatal accidents have occurred from the use of ether Chloroform or gas and oxygen are generally employed, but C E mixture in the usual proportions appears to be safe unless the operation is actually intra oral If any spirituous solution has been applied to the skin just before the operation it must be carefully mopped dry before the diathermy is switched on, or it will catch fire

Damage to important structures —Only a practised operator with a nicely regulated machine may venture to use the diathermic needle in the neighbourhood of large vessels and nerves or other vitally important structures It is easy to penetrate a large vein or so to devitalize its wall that secondary hæmorrhage will occur For dissection of the axilla the method is unsuitable, but when used with skill and discretion diathermy facilitates the earlier stages of gland dissections of the neck, and of thyroid operations A thin skin-flap may be casually penetrated in a moment of inattention or from failure of the assistant to keep the parts on the stretch For obvious reasons no accidental contact between the needle and any metal instruments lying on the field of operation must be allowed

Occasional impairment of primary union —Primary union takes place satisfactorily after even very large cutting operations by diathermy if the cutting has been done rapidly, without visible charring of the cut surface and without undue heating of the subjacent tissues If these conditions are not fulfilled, and of course if there is failure in asepsis suppuration is probable The most likely cause of failure is the omission to sterilize by boiling the needle, its handle, and the cable which connects it with the machine Sterilizable cables are not usually supplied by the makers but they are obtainable and should be insisted upon

About ten days after a diathermy operation there may be a phase of lowered resistance to the patient's own skin organisms, indicated by a rise of the previously normal temperature, and by reddening of the skin edges of the wound The irritation usually subsides rapidly when the wound is sprayed with staphylococcus antivirus, but in rare cases suppuration may appear and may extend under the flaps The process seems to be a kind of fat necrosis

Phlebitis —The application of the neutral electrode to the thigh should be avoided In two patients, who had previously suffered from phlebitis, acute saphenous and femoral phlebitis occurred after the operation, and one of them succumbed to a staphylococcal septicæmia

Transmission of the current through the thigh had apparently stirred into activity a latent focus of residual infection in the veins

Burns from the plate electrode —Any uncovered part of the neutral or plate electrode will burn any portion of skin touched by it since the current following the line of least resistance will concentrate upon the uncovered area The plate electrode should be wrapped completely in several layers of a towel wrung out of strong saline (a handful of salt to the pint) It is best placed behind the loins with a small cushion like pad beneath it to hold it in close contact with the skin aided by the weight of the patient

Most of the dangers associated with diathermy are avoidable with due care In a large majority of cases after an extensive cutting operation by this method perfect primary union results and con valescence is uneventful

It seems certain in view of its special advantages in cancer surgery that diathermy will replace the knife to a large extent I habitually used it in the radical operation for breast cancer for ten years but have lately come to the conclusion that the scalpel is preferable for such a large operation

Coagulation diathermy —If the surgeon decides not to cut out a tumour in a difficult or inaccessible situation it may still be destroyed *in situ* by diathermy The needle electrode is plunged into the tumour and carried down to within 1 cm of its deep aspect The current is turned on until an area of coagulation 1 to 2 cm in diameter appears round the needle which is then removed and re-introduced about 2 cm away from the first puncture The process is repeated until the whole area has been dealt with

As a cauterizing agent the diathermic needle is much more efficient than the Paquelin or electro-cautery because its range is greater If the current is kept on for too long a dry eschar of high electrical resist ance forms round the needle sparking occurs and the needle adheres to the destroyed tissue so that bleeding follows its withdrawal

Risks of coagulation diathermy —When diathermy is used to coagulate and destroy an area of tissue *in situ* with a view to its subse quent separation as a slough the process of separation is an inflam matory one attended by certain risks Œdema always occurs round the coagulated area and lasts for several days Œdema of the glottis may supervene if the growth is near the superior aperture of the larynx Stricture may follow diathermy of the œsophageal growth Secondary hæmorrhage and broncho pneumonia may occur for the sloughs often become very foul As a rule the separation of the sloughs is accom panied by little pain and the wound heals well

Great caution must be used in employing diathermy close to a bone for necrosis is likely In some cases the risk must be accepted if the alternative is incomplete destruction of malignant tissue

Operative treatment of recurrence —It is difficult to lay down clear rules for the operative treatment of recurrence If however the

recurrence is single movable and accessible prompt operation should be performed unless upon consideration it is decided to trust to radiation In this choice the feelings of the patient will play a great part The issue of a recurrent case is necessarily uncertain and it is as unfair to thrust operation upon a reluctant patient as to refuse it to one eager to seize every chance Frequently the ideal treatment is a combination of excision and radiation

Of course a recurrence even if single is likely to be followed by recurrence at other points but this is not inevitable especially if thorough X ray treatment is given subsequently Sometimes after excision of the recurrent lump the patient remains well for years and even permanently In order to exclude other recurrences operation should be preceded by a specially thorough examination of the patient and by radiological examination of the chest A pelvic examination should always be made

RADIUM IN THE TREATMENT OF MALIGNANT DISEASE

The position of radium in the treatment of malignant disease is now so secure that a brief comparison of the various methods of using it is essential

Surface application of radium—In the past surface application of radium has been extensively used in the treatment of malignant disease The radium collar is still employed in some clinics for secondary cervical glands but in my experience the results of this and of most attempts to treat malignant disease by surface applicators are unsatisfactory Even in rodent ulcer which is the first and last stronghold of surface radiation interstitial radiation seems to be preferable unless the disease is in a very early stage I have seen cases of rodent ulcer where superficial healing was accompanied by active progress in the deeper parts

Except in ulcerated growths it is usually necessary to use a screen or the skin will be injured by the α and β rays before an adequate dose of γ rays has been administered Even if the α and β rays are filtered off by 1 mm of platinum or its equivalent the lethal dose for a carcinoma-cell is rather greater than the dose which the normal skin can endure without injury It may be doubted therefore whether a cancer-cell situated just beneath the skin (much less one situated deeply) can be destroyed by a surface applicator

Buried radium—The source of radiation will act much more effectively if it is brought into close proximity with the neoplastic focus Its action on the cancerous tissues will be much greater its action on the normal tissues much less It is here that radium possesses a great advantage over X radiation A radium needle or a tube of radium emanation can be buried in the tissues for a longer or shorter period and a branch of surgery to which the name radio surgery may be applied is thus evolving Radio surgery includes a study of the use of radium needles during the course of operations of ablation

Buried radium as an adjunct to operation —Whenever it is doubtful whether a small malignant focus has been completely excised, radium needles should be laid in the suspected area of the bed of the wound at the time of operation, and removed after an appropriate interval Thin skin flaps should be carefully shielded from undue action of the radium by the interposition of a wad of gauze It must be remembered that the lethal range for carcinoma-cells of a 25 mg tube of radium element acting for twenty-four hours through 1 mm of platinum certainly does not exceed an inch The needle or needles are withdrawn in twenty four hours, or are removed into a second position for a further twenty four hours An anæsthetic is usually unnecessary for their removal Less powerful needles may be used for longer periods, and are preferable Thus a 2 or 3 mg needle may safely be left in the subcutaneous tissue for a week

My special application of buried radium as a routine procedure during the operation for breast cancer is described at p 630

The use of radium may convert an operation doomed to failure by obviously and necessarily incomplete removal of the growth, into a permanent success Thus in an abdomino perineal operation for rectal cancer I observed nodules of growth on irremovable areas of the pelvic peritoneum overlying the back of the bladder A radium tube was left in the pelvic cavity for twenty-four hours, and more than twenty years later the patient remained well He ultimately died without recurrence

It may prove to be possible, by the use of radium during operations to restrict the undue extent and severity of some operations for cancer Thus in cancer of the rectum I have of late years, returned to the perineal method of operation combining it with the use of radium By the perineal method the complete removal of the glands in the mesorectum is impossible, and therefore by itself the method is incomplete but the routine introduction of a 50 mg tube of radium into the mesorectum high up for 24 hours will, I hope, compensate for this defect in the method and prevent recurrence in the glands The method is at present on its trial

Massive distance treatment by radium (bomb method).—The use of a large mass of radium of one to ten grammes at a distance of 10 cm or more from the surface of the body is now a well established method especially for deep seated glandular masses in the neck, and for primary growths of the tonsil and the post cricoid region It has been found necessary to install a second four gramme bomb at the Middlesex Hospital, owing to the favourable results attained by Dr Windeyer with the bomb first installed The advantage is that, without a surgical operation of access, a practically uniform intensity of radiation can be delivered through the skin to a considerable thickness of tissue It is however, impossible to limit the effect to the part it is desired to treat The depressing constitutional effects of radiation are difficult to avoid and may be serious

Interstitial radiation. Radio-surgery.—For most cases of malignant disease radiation is most effective when the sources are within the body, evenly dispersed through the area in which malignant cells are found. The diseased tissues then receive a maximal dose of radiation since they are nearest the source. What is equally important, the body generally receives a minimal dose. General or constitutional radiation, speaking broadly, is a harmful factor which should be reduced to a minimum. After heavy doses of short-wave X-rays, and after radium-bomb therapy, vomiting, cardiac failure with feeble pulse, intense depression, and aplastic anæmia may persist for months or may even be fatal. Extreme misery and a loss of all desire to live are among the more severe effects of excessive radiation.

The great advantage of the method of radiation by implanted tubes of radium or radon, first introduced by Dominici, is that for a given amount of radiation of the tumour tissue, the normal tissues of the body receive the least possible dose, so small that it usually exerts a stimulating and not a depressing effect.

The method has a disadvantage in that it necessitates a surgical procedure. In simpler cases the tubes are introduced through multiple punctures in the skin and mucous membrane. Frequently, however, in the deeper-seated growths, if they lie in contact with vital structures, an incision is necessary or at any rate advisable. The needles can then be accurately placed without fear of injuring important adjacent structures such, for instance, as the great veins of the neck or the nerve-trunks.

The first essential in approaching the treatment of a case by buried radium is to form an accurate idea not only of the exact limits of the primary growth but of the extent to which infiltration or permeation —microscopic and therefore inappreciable—has occurred around it. In those growths which infect lymphatic glands, a precise knowledge of the lymphatic anatomy of the part is essential, and also a working knowledge of the probable range and direction of secondary invasion of the glands Beyond the enlarged glands there are microscopically infected ones, and recurrence is certain if treatment is restricted to glands palpably enlarged.

Having settled in his mind the exact area which requires radiation, the surgeon's next care is to ensure the uniform and adequate radiation of this area, a task made much easier now that it is the custom to employ many small needles of radium of the order of 0·5 to 3 mg. rather than a few powerful ones of 12 to 25 mg. Even now, however, the proper distribution of the available tubes is a very difficult matter. Even in skilled hands it is probable that an ideal distribution is rarely attained In unskilled hands gross maldistribution is practically inevitable

H. A. Colwell, who has written a clear and timely introduction to the study of radium-therapy* says: "It is impossible to emphasize too strongly that radium treatment is not a kind of easy substitute

* *Notes on Radium Therapy*, H. K. Lewis, 1931, p. 64.

for surgery The insertion of radium demands, and to the full, all the knowledge of anatomy, pathology, and surgical technique that does ordinary surgery—it demands all this and, in addition, some knowledge of the physics of radium, and of the action of radiation "

It must be remembered that, with a point source, the intensity of radiation per unit of surface varies inversely as the square of the distance of the source of radiation from the radiated surface If the intensity at a distance of 1 cm be taken as 1, the intensity at a distance of 2 cm is only $\frac{1}{4}$, and at 3 cm $\frac{1}{9}$ This rapid fall in intensity greatly limits the surface use of radium, for at a short distance beneath the skin surface the intensity falls below the minimum necessary for therapeutic effect In most cases the method of burying the radium tubes is much to be preferred Even by this method the effective range of the rays hardly exceeds an inch

Action of radium on the tissues —A sufficient dose of radiation will destroy either normal or neoplastic tissues, but the latter are more sensitive In the tumours most amenable to radiation—namely, rodent ulcer and lympho sarcoma—only a fraction of the dose which would destroy normal tissues is required

The sensitiveness of normal tissues varies greatly Gland epithelium is very sensitive, squamous epithelium less so, muscle still less

Besides the direct destruction of malignant tissue, the treatment may possibly be useful by producing an immunity reaction, but personally I have not been able to convince myself of the existence of such a reaction in carcinoma or of any " systemic " effect of radium on the cancer-cell, a conclusion borne out by the recent laboratory researches of the Imperial Cancer Research Fund Broadly speaking, the problem is to administer a lethal dose of radiation to every cancer-cell in the body, without injury to the normal cells The difficulties are numerous, and in many cases insuperable

The action of radium, local, and of short range —It is possible to introduce radium emanation in solution into the veins, and so to convert the blood temporarily into a radio active solution I have tried the method in disseminated malignant disease with only temporary benefit The diffused radiation is too weak to be effective To destroy a cancer-cell it must be brought for a period of some hours within a distance of an inch of a source of radiation of high potency, such as a 12 or 25 mg tube of radium, or for a longer period of, say, a week within the same distance of a 2 or 3 mg tube Consequently, radium is powerless to deal with disseminated malignant disease, or even with a large primary mass of growth Where a large area has to be covered, X-rays must be used On the other hand, *within its range of action*, clinical experience shows that radium is much more effective than X-rays, and nowadays that range has been increased by the use of multiple small needles of radium, perhaps twenty or thirty in number, spread out over a considerable area Although large areas may be covered by X-rays, clinical experience until recently seemed to show that their destructive

action on malignant cells does not extend very deeply beneath the skin perhaps not to a depth of an inch But in the last two or three years and in the hands of a few skilled radio therapists spinal bone and pleural secondaries have been retarded or even arrested by high voltage X ray treatment with relief of pain restoration to subnormal activity and prolongation of life Such benefits are not to be despised even if their duration is limited for they postpone and abbreviate the final phase of complete disability and may make it almost painless

Seitz and Wintz introduced the biological system of measuring radiation according to its effect on the tissues They attached the arbitrary figure 100 to that dose of radiation which in eight days will produce a slight erythema and in four weeks a slight pigmentation of the skin This they called the unit skin dose They stated that the lethal dose for a sarcoma cell is by comparison 60 or 70 (i e 0 6 or 0 7 of the unit skin dose) while the lethal dose for a carcinoma-cell is 90 to 110 These figures are useful if rough approximations

The difficulty of getting the lethal dose to a depth beneath the skin may be estimated from Dr Knox s statement that using a beam of rays at a voltage of 90 000 to a 9 or 10-in spark gap only 5 to 7 per cent of the beam reached a depth of 4 in beneath the skin surface The lethal dose for a carcinoma is rather greater than the skin can endure without injury

Radium needles—Radium needles to be buried in the tissues should be torpedo shaped with a pointed end to facilitate penetration The other end of the tube should be hemispherical without any projecting shoulder to make withdrawal difficult Through the base and close to it (an important point) is drilled a small hole to take a piece of stout silk or fishing gut which serves to withdraw the tube Unless the hole is drilled close to the base the tube will tend during withdrawal to assume a position transverse to its track whenever it meets with a slight obstacle

The most useful strengths of the needles are 2 and 3 mg of radium element It may be usefully remembered that according to Prof Sidney Russ two 25 mg tubes 3 cm apart will in twenty four hours administer a lethal dose of radiation to any carcinoma cell intervening between the tubes In my experience a 25 mg tube ½ in beneath the skin will in twenty four hours cause such changes in the skin as to produce after a latent period a superficial dermatitis severe enough to leave a visible permanent discoloration or a superficial scar Small needles of 2 or 3 mg not nearer than half an inch apart may be left for five to seven days or even longer if they are not immediately beneath the skin

Introduction of needles—A puncture is made through the skin and deep fascia A special pair of radium forceps constructed to hold the needle firmly without injuring it is used as the introducer The tube may be finally pushed into position by a pusher with a concave end which will not slip off the convex end of the radium needle The

loop of fishing-gut attached to the needle hangs out of the wound, which may be closed temporarily by a half-tied suture When it is desired to take out the needle, the loop of the suture is loosened, the needle is withdrawn, and the stitch is then tied permanently

The introduction of the radium needle may be a very simple or a difficult and delicate operation, according to the site of the implantation Undue force in introduction may bend or deform the needle Only practice can teach the degree of force permissible, it varies with the thickness and length of the needle During introduction a needle may penetrate a large vein, and a serious operation may be necessary to reach the bleeding vessel Difficulties may arise in withdrawal owing to the breaking of the loop of string attached to the needle, or to the needle wedging itself transversely across the track The latter difficulty is generally due to incorrect design of the needle

In radio surgery the surgeon acts as a radiologist, and he will do well to call in a radiologist to advise and co-operate with him A few elementary facts about radium may here be stated

Sources of radiation —The sources of therapeutic radiation practically are two radium and X-rays The technique of X-rays and of the surface application of radium does not concern the surgeon His interest lies in the use of radium by operative methods

Physics of radium —Radium is an unstable element which is undergoing a process of exceedingly slow decay In this process it gives off a gas called radium-emanation which is the actual source of its radiations When radium is in a sealed tube the emanation attains a certain pressure, which thereafter remains constant Radium emanation decays rapidly, losing half its radio-active strength in forty-eight hours For therapeutic use, apart from radium itself, it must therefore be freshly prepared On the other hand, the radio active strength of a sealed tube containing radium or one of its salts rises to a maximum in about a month, and is subsequently constant

Radium, or rather its emanation, gives off three classes of rays—α-, β, and γ- rays The α-rays are particulate and are arrested by any surface on which they impinge They are valueless for deep therapy The β rays are electrons of low penetrative power and very irritant to skin surfaces, they can be to a large extent arrested by a screen of 1 mm of platinum or 2 mm of lead When this is done the γ rays alone penetrate the screen These are rays of great penetrative power, and from them the therapeutic virtues of radium are mainly derived

In order to obtain filtered γ-rays radium salts in amounts of 0 5 to 25 mg are sealed up in platinum tubes, and these again are enclosed in outer tubes The total screenage usually employed is 0 6 to 1 mm of platinum

Principles governing the use of buried radium —It has been thought that in the treatment of a mass of malignant tissue the governing consideration should be so to dispose the available needles through its substance as to give a uniform dose of radiation to the whole mass This conception is unsound in that it fails to take into account the

invisible zone around the mass in which permeation or infiltration is taking place. It is possible that small doses of radiation stimulate malignant cells. Accordingly it is not surprising to find that in many cases where a successful attack is in this fashion made only on the visible and palpable deposit of growth its disappearance is rapidly followed by the appearance of multiple small fresh nodules of growth in the near neighbourhood (Fig 323)

Pathology shows that all large aggregations of cancer-cells are degenerate in their central portions. A visible lump of cancer is com

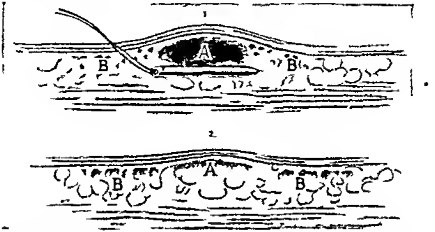

Fig 323.—To show frequent result if radium needle is buried beneath visible growth (A) to neglect of surrounding zone (B B) of inappreciable microscopic infection.

In 1 the tube is seen in position beneath the growth; in 2 some weeks or months later the growth has shrunk and become fibrotic, but in the zone B B visible and palpable nodules of growth are evident.

paratively negligible; the active enemy is to be found in the apparently normal tissue around it.

Encirclement method.—It is for this reason and to avoid small dose stimulation of the remoter cancer cells that I advocate what I may call the encirclement method of using buried tubes. The needles should be disposed in a circle around the nodule. They should lie in the plane of the main lymphatic plexus of the part, for in this plane permeation is likely to be spreading. Roughly speaking they should be ½ to ¼ in from the palpable edge of the mass (Fig 324)

If in this way the actively advancing isolated cells of the growth can be killed and the lymphatics which lead from it sealed by an inflammatory reaction the further spread of the disease will be checked. The visible nodule already probably degenerate can if necessary be attacked directly on a subsequent occasion by burying needles actually in its substance; but often it will shrink or disappear, for its periphery, the most active part of it, will have received an adequate dose and even its centre may have received enough radiation to kill the degenerate cells there to be found.

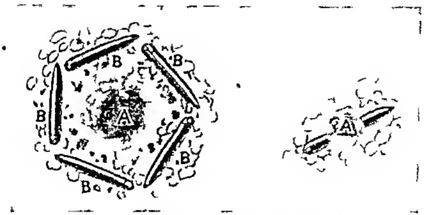

Fig 324 —Encirclement method of using radium needles

The method ignores at first the visible growth A and aims primarily at the destruction of the microscopic deposits present in the surrounding zone B The second drawing shows the consequent disappearance some weeks later of the zone B The visible growth A is reduced in size and is now dealt with by burying a radium needle beneath it In both drawings it is supposed that the superficial tissues have been sliced away to demonstrate the radium needles in position

The encirclement method may be compared to the device of hunting wild animals by enclosing them within a continually narrowing ring of beaters and driving them towards a centre On the other hand methods which pay attention only to the visible nodule of growth disperse the game over the whole country I am not unmindful of the practical difficulties of the method It requires a number of needles though the number may be halved by making each needle take up in succession for equal periods two positions on the periphery of the circle That is to say at the end of the chosen period the needle more deeply introduced at first and tangentially to the circle is only half withdrawn This device may be called the snail track method (Fig 325)

If the amount of radium available is inadequate the treatment of the case should not be undertaken

The modern technique of using numerous small needles instead of a few large ones has greatly increased the area it is possible effectively to radiate and it is now generally possible to radiate both the palpable tumour and the zone of infiltration around it at the same time Nevertheless the principle of the encirclement method remains valid though it is sometimes still forgotten I recently saw a case of carcinoma of

Fig 325 —" Snail track method of using radium needle

At the proper time after its introduction the tube is made to take up a second position Its radius of action is thus enlarged without the necessity of a second operation

the hard palate treated by interstitial radium The primary growth was replaced by a radium ulcer, but round it were numerous tiny nodules of active growth The width of the zone of infiltration and permeation had been underestimated

The place of radiation in the treatment of malignant disease.—The place of radiation in the treatment of malignant disease is one of steadily increasing importance, and a brief attempt must be made to estimate the relative claims of operative and of radiological treatment The difficulty consists not only in the rapid changes which are taking place in radiological treatment, but in the separation of the two branches of practice one from the other. The radiologist is apt to make undue claims, while the surgeon fails to realize the help which radiation can give Broadly speaking, it may be said that success in the treatment of malignant disease depends upon the intimate co-operation of the surgeon and the radiologist

When the first edition of this work was published in 1924 the position was summed up by the late Dr Robert Knox's words at the 1922 Congress of Radiology —

" My practice is to recommend operation wherever it is possible, and to follow up operation by radium and X-ray exposures Thorough irradiation treatment on intensive lines appears to be the more rational procedure The border line case should have the benefit of radium locally and full X ray doses from the periphery, especially if operation is decided against The inoperable cases should be treated with full radium exposures, followed by X rays . . .

" In my opinion, the time has not yet come when radiotherapeutic measures should displace the surgical A great deal of research work must yet be done before we can safely take up such a strong position

If the claims of the Erlangen school can be substantiated, one of the most important advances in medical history has been made We cannot in this country support the claim put forward I await the events of future years to prove or disprove the value of that opinion

From an experience in the treatment of cancer now extending to nearly twenty years, the results obtained so far are not nearly encouraging enough to warrant even the hope that we have in X-rays and radium a specific cure for cancer

" I am convinced however, that in these agents we possess useful aids in the treatment of malignant disease, particularly for the amelioration of suffering and relief of symptoms, and that all efforts should be made to carry on the investigations into the physical properties of the agents and particularly to investigate very thoroughly the biological reactions induced by their application

Events during the last fourteen years have shown that Dr Knox correctly forecast a great increase in the powers of radiology The epoch making work of Regaud at the Paris Radium Institute has practically eliminated ablation operations for cancer of the tongue He has shown that treatment of the growth *in situ* by buried radium needles gives far better results than any operative method Regaud

appears to have taken as his starting-point the observation of Lazarus Barlow that squamous epithelium is more affected by a small dose of radium acting for a long time than by a large dose acting for a short time Instead of burying powerful tubes of 12 to 25 mg of radium element for a short period such as 24 hours, he employed needles of 2 or 3 mg. for a period of 5 to 7 days He furthermore insisted upon the necessity of securing an equal intensity of radiation throughout the whole mass of the tumour and the infiltrated area around it, and accordingly he used a number of needles closely set and carefully distributed to secure uniform intensity throughout the treated area He was thus able to secure regression and local disappearance of the primary growth without destruction of the surrounding normal tissue, and his methods are now followed all over the world

He was less successful in the treatment of secondary gland deposits by radiation and up to the present time a complete dissection of the glands of the neck on one side or both sides remains the method of choice for dealing with gland deposits It may be supplemented, but cannot at present be replaced, by the implantation of radium in the tissues of the neck

Further advances in the use of radium have been made by the Stockholm school who have devoted their attention especially to cancer of the cervix, and have made radium at least an equal competitor with operation in the treatment of this disease

In the radium treatment of breast cancer the lead has been taken by this country Having convinced myself seventeen years ago that breast cancer invades the internal mammary glands just as early as it attacks the axillary glands, it became clear that every extrathoracic operation for breast cancer is likely to be an incomplete one Since that date I have used radium needles, inserted along the line of the internal mammary glands in all my operations for breast cancer, with a definite improvement in the results

Mr *Geoffrey Keynes in 1924, adopting a technique similar to that* of Regaud in cancer of the tongue, advocated a treatment of breast cancer by buried radium alone instead of by ablation and met with a notable degree of success, but his experience has gradually led him back to a combination of limited operation with radium This question is dealt with in more detail in "*Operations on the Breast,* p *598*

For cases near or beyond the limit of operability and for old and feeble patients, operation has been definitely replaced by interstitial radiation For such cases the Keynes technique represents a great advance, but it should not be used for left sided breast cancer in patients with cardiac disease

In carcinoma of the rectum radium has proved very disappointing While the abdomino perineal operation has largely fallen into disuse on account of its mortality, which remains relatively high, the perineal operation more than holds its own against attempts which have been made to replace it by interstitial radiation W B Gabriel * from the

* *Brit Journ Surg* No 78 1932, xx 234

experience of St Mark s Hospital has recorded 189 cases of perineal excision of whom 45 were alive and well five years after operation Among 12 operable cases treated primarily by radium needles only two good results were achieved by radium alone In six of the cases subsequent perineal excision became necessary In Gabriel s opinion based upon sixteen cases intra abdominal radiation after laparotomy has a high operative risk which its late results do not justify when compared with the results of simple palliative colostomy

The posterior barrage operation of Gordon Watson gave good results in two cases out of nine but three postoperative deaths from toxæmia occurred and one from secondary hæmorrhage It appears that the tissues round a rectal carcinoma are often the seat of a secondary bacterial infection and that sloughing and infection usually result if they are radiated through a surgical wound

The scope of radium in carcinoma of the rectum thus appears to be a very limited one but in my opinion it may be usefully employed (1) as a routine to deal with the high mesorectal glands at the time of perineal excision (2) in the lumen of the bowel as a palliative to check hæmorrhage and delay the growth after colostomy and (3) for epithelioma of the anal margin

In carcinoma of the lip the tongue and the oral cavity generally except for carcinoma of the hard palate and perhaps of the alveolar margin radium has definitely replaced the knife in dealing with the primary growth It is however generally agreed that in this group of carcinomata radium has proved unsatisfactory for secondary gland deposits and for the primary growth if it is adherent to the bone A complete unilateral or bilateral dissection of the glands from the mastoid to the sterno-clavicular joint should as a rule be undertaken

The therapeutic radiation of a carcinoma of the hard palate usually causes necrosis of the underlying bone and gives an unsatisfactory result In carcinoma and sarcoma of the upper jaw the use of embedded radium tubes is inevitably followed by necrosis and persistent pain though the growth may be arrested The best result is attained by excision of the maxilla followed by radium radiation of the resulting cavity Such at least is my own experience

For carcinoma of the penis excision of the growth or amputation of the penis need no longer be practised since radium gives very good results without mutilation Surgical excision of the glands in the groin is preferable to radium which may lead in this situation to sloughing and secondary hæmorrhage

Osteo sarcoma can usually be treated more successfully by interstitial radiation than by amputation At the London Cancer Conference of 1928 I showed a small group of such cases successfully treated by radium alone If the disease is only partially arrested by radium an amputation can still be undertaken and I think with a better chance of success than if no radium has previously been used

Radio-surgery of inaccessible growths—Certain varieties of malignant growth inaccessible to the surgeon s knife can now be treated

Fig 1 July 1919

Fig 2—August 19 0

PLATE III Mediastinal tumour

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Radio-surgery of inaccessible growths.—Certain varieties of malignant growth inaccessible to the surgeon's knife, can now be treated


Fig. 1.—July, 1919.


Fig. 2.—August, 1920.

PLATE III.—Mediastinal tumour.

Fig. 3. January 1923.

Fig. 4. July 1923

PLATE IV. Mediastinal tumour (same case as Plate III)

hopefully by buried radium Operations of some gravity and delicacy may be requisite to introduce the radium needles into the desired position It is especially in growths of the prostate, pancreas or anterior and superior mediastinum that the method promises well I have also used it with some temporary benefit for the abdominal glandular deposits of malignant disease of the testis In a case of new growth of the lung, although the growth diminished greatly in size, the introduction of radium needles into the lung substance led to infection from the bronchi, with purulent bronchitis and bronchiectasis Death occurred within a few months, and I would not again insert radium into the substance of the lung My attempts to deal with gastric cancer by intra abdominal radium have been equally unsuccessful Encouraging results have in several cases followed the treatment of cancer of the pancreas by radium needles introduced behind the pancreas through an abdominal incision My plan is to incise the peritoneum to the right of the duodenum and bring that viscus forward Owing to the fibrosis of the growth which follows its radiation obstruction of the common bile-duct and of the duodenum is a likely sequela and gastro enterostomy and cholecyst-duodenostomy should be done either at the time the radium tubes are introduced or later when jaundice and duodenal obstruction supervene A survival of several years in comparative comfort may then be attained *

Carcinoma of the prostate —One of the most promising fields in the radium therapy of malignant disease appears to be carcinoma of the prostate Operative removal of the disease is almost hopeless, though a percentage of early malignant prostates are mistaken for adenomatous enlargement and are enucleated sometimes with great difficulty, a quick return of the disease is the rule even in these early cases In malignant prostate which can be diagnosed operation is out of the question, for Young's results after perineal prostatectomy in this disease have not induced other surgeons to adopt his operation Thus, at the earliest moment cancer of the prostate can be diagnosed, radium-therapy holds the field against operation The condition appears to be favourable to its application The malignant growth is enclosed in a dense wall of fibrous tissue, the prostatic sheath, which strongly opposes its spread in every direction except upwards towards the bladder Pressure on the urethra gives rise to a degree of urinary obstruction which enables the disease to be diagnosed fairly early, while the mass is still small enough to be hopefully dealt with by radium The upward spread is accessible to radium needles introduced into the bladder The glands first affected lie just on the lateral aspect of the prostate, and are also accessible to radium needles introduced in the way I shall describe

The early attempts at radium-therapy were made by introducing a radium tube into the prostatic urethra and leaving it there for some hours It seems to me that the introduction of radium into the sensitive prostatic urethra, and necessarily in close contact with its mucosa, is

* Upon this subject the writer's paper in *Annals of Surgery* July 1934 c, 215 may be consulted.

an undesirable proceeding, likely to aggravate the discomforts of urination already present A similar criticism applies to rectal introduction The radium needles should lie as far as possible away from the mucous membranes of the rectum and urethra They should lie as close as possible to the point where lymphatics leave the prostate to enter the closely adjacent lowest internal iliac lymphatic gland

The method I have adopted to fulfil these indications is to place the patient in the lithotomy position with a staff in the urethra A finger of the operator s left hand keeps guard in the rectum Two punctures are made through the skin of the perineum, in front of the anus and on either side of the bulb An artery forceps is now thrust upwards into

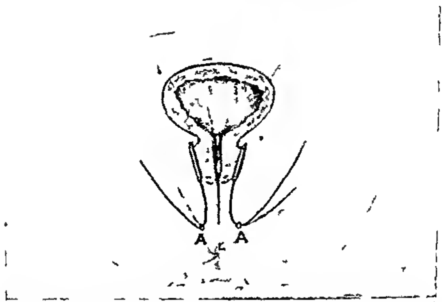

Fig 326—Schematic drawing to show introduction of radium tubes into prostate through punctures in perineum.

The tubes lie upon the lateral aspect of the prostate well away from the urethra, and near the lymphatic glands which receive the lymph from the prostate A A The punctures in the perineal skin.

the prostatic substance close to the lateral aspect of the gland and is replaced by a 25 mg radium tube mounted on a stout silver wire The procedure is repeated on the other side The projecting ends of the wire are bent forwards so as to lie in the recess between the scrotum and the thigh They are sheathed in a piece of rubber tube and kept in position by a firm perineal dressing They remain in position for twenty four hours (Fig 326)

This procedure is sometimes followed especially about the third week, by an increase in the frequency and pain of micturition but after this there is usually striking relief and improvement lasting for months or years I have one patient who remains well at the end of ten years

I now supplement the method by introducing a third tube, contained in a catheter, into the bladder itself, so as to act on the prostate from above with less risk of irritating the prostatic urethra

The constancy and definiteness of the improvement which occurs after intraprostatic radium treatment justifies the hope that, as our methods improve, definite cure may in this way be attained In any case, however, I would strongly urge the use of radium-therapy at the earliest possible moment It has no competitor in relieving the patient's distress, and this applies both to the pain and to the difficulty of urination

Illustrative case —William B, æt 75, was admitted to the Middlesex Hospital under my care for carcinoma of the prostate He was suffering from constant lumbar pain, with occasional violent prostatic pain A catheter had to be passed three or four times daily The prostate was enlarged, hard, and nodular The urine contained blood and pus A tube of 25 mg of radium element was inserted into each lateral lobe for twenty-four hours No catheter had to be passed subsequently, though retention had been complete before operation The patient left the hospital free from pain, and passing, without straining, a good stream of urine

The late Mr Hastings Gilford, of Reading, who subsequently had the patient under observation, informed me that he died of secondary deposits about a year later but that urination remained free and comfortable to the end

Radium in growths of the anterior and superior mediastinum — In sarcoma of the mediastinum, and especially in lympho sarcoma, great benefit can be obtained from treatment by buried radium The subject is not ripe for general statements, but the methods recommended can be inferred in general outline from the following case-records —

Annie M, æt 34, was sent to me by Dr Washington Isaac in August, 1917, for lympho-sarcoma of the anterior mediastinum, first manifesting itself in the 2nd left costal interspace The diagnosis was confirmed by the microscope Radium caused disappearance of the mediastinal growth, but the disease re-appeared in the glands of the left posterior triangle Here it again yielded to radium, X-rays, and arsenic, so that in October, 1918, there was no sign of recurrence In February, 1919, dullness and fullness over the sternum appeared again, but again yielded to external applications of the 5 g of radium then available at the Middlesex Hospital Up to March, 1921, she did her ordinary work, but in November, 1921, there was dullness over the whole of the upper part of the left lung, and her time was evidently short Radiation treatment, however, gave this patient four additional years of useful and active life

In a similar case, with my present experience, I should resect one or more of the costal cartilages in order to introduce radium needles more deeply and widely in the anterior mediastinum (Fig 327)

Hubert S, æt 21, late of the Flying Corps, was operated on for a lympho-sarcoma of the mediastinum bulging to the right of the aorta, by Mr A J (now Sir James) Walton, in August, 1919 I was asked to be present to introduce radium The mediastinum was opened and a

quantity of necrotic tumour material evacuated Radium (100 mg) was placed in the cavity The operation was followed by complete disappearance of the radiographic, ausculatory, and subjective signs of thoracic tumour and the patient appeared quite well until September, 1920, when a radiograph again revealed a shadow to the right of the aorta With Mr Walton's concurrence, I resected the 2nd right costal cartilage in order to introduce 100 mg of radium deep in the swelling, for fifteen hours The shadow again disappeared, and until July, 1921, remained in abeyance Some slight discomfort in breathing at this time led to the taking of another skiagram by Mr E W H Shenton Conditions on the right side were normal, except for some slight patchy

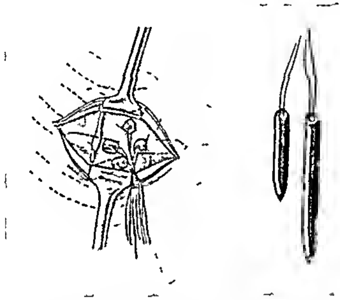

Fig 327 —Removal of second right costal cartilage for introduction of radium needles into growth of superior mediastinum

opacity to the right of the aorta but a definite rounded shadow extended the aortic opacity to the left The 2nd left costal cartilage was resected, and 100 mg of radium was introduced into the mediastinum in the region of the tumour As a precaution a 25 mg tube was also introduced on the right side A radiograph taken two months later was practically indistinguishable from a radiograph of the normal chest However, in December, 1921, there was a re development of the growth to the right of the sternum, and further treatment was necessary Radium (125 mg) was buried to the right of the sternum for twenty-four hours and 25 mg to the left of the sternum Radium treatment was supplemented throughout, and during the last two years replaced by X ray treatment given by Dr R Knox Early in 1924 dyspnœa, and dullness at the base of the right lung, appeared Death occurred in March, 1924, four and a half years after the first operation For

nearly four years after the treatment of this apparently hopeless case was begun, the patient lived a fairly normal life, and he was travelling abroad as late as 1922 Plates II and III, four radiographs by Dr Knox, show the condition of the thorax at different periods

Postoperative prophylactic X-radiation —Most surgeons, unless for malignant growths refractory to X rays, such as squamous carcinoma and melanotic sarcoma advise a subsequent prophylactic course of high-voltage X-rays In my opinion this precaution is valuable and never to be omitted In breast cancer it certainly lowers the percentage of superficial recurrences in the region of the scar The course should be a short one, not so severe as to lower the patient's general health, vitality, and power of resistance The aim should be to irradiate a wide circle around the point where the growth started This area must be accurately centred, and in the case of breast cancer should be a circle 12 in in diameter so as to include any portion of the microscopic growing edge which may have escaped operative removal I have seen the best results where the X-rays without injuring the skin, have produced deep pigmentation over a wide area The technique of postoperative X radiation is purely a matter for the radiologist, and cannot here be discussed

CHAPTER XIII

OPERATIONS ON THE BREAST

By W. SAMPSON HANDLEY

Lymphatic anatomy. **Axillary glands**—Poirier and Cunéo describe the lymph glands of the axilla as grouped in three main chains, following respectively the axillary, the external mammary, and the subscapular arteries and converging to an apical group of subclavicular glands In addition, there is a central group embedded in the fat of the axilla

1 The *humeral chain* comprising four or five glands, accompanies the axillary vessels lying internal to the vein Glands forming a downward continuation of this chain follow the upper course of the brachial artery and may be found cancerous in some late cases of breast cancer—a fact first pointed out by Lockwood The humeral glands receive most of the lymphatics of the arm Their efferent vessels terminate in the central group, the subclavicular glands, and in a gland situated above the clavicle in the subclavian triangle

2 The *thoracic chain* consists of two or three glands placed in the second or third intercostal space in front of the trunk of the external mammary artery just under cover of the lower border of the pectoralis major These are the glands first affected in breast cancer In addition, there are in this group two or three glands placed behind the external mammary vessels in the fourth and fifth intercostal spaces The anterior thoracic glands receive lymph mainly from the breast and the muscles lying behind it the posterior thoracic glands receive lymphatics from the lateral wall of the thorax The efferents of the thoracic chain mostly end in the glands of the central group, but generally a few vessels pass direct to the subclavicular glands

3 The *scapular chain* of six or seven glands lies along the subscapular artery in the groove separating the teres major from the subscapularis, and is not affected early in breast cancer, since its efferents mainly come from the scapular region It empties into the humeral and central glands

4 The *central group*, three to five in number, lies near the base of the axilla and receives efferents from the preceding groups having no lymphatic territory of its own Efferent vessels pass to the subclavicular glands

5 The *subclavicular* glands (often called subclavian glands) consist of six to twelve glands lying at the very apex of the axilla, below the clavicle, above the pectoralis minor; behind the great pectoral and the costo-coracoid membrane, and internal to the axillary vein It is best not to call these subclavian glands, for the name, though literally accurate, suggests a relation to the subclavian artery which they do not possess Internally, they rest on the first digitation of the serratus

magnus They possess great surgical importance, for they are often affected early in breast cancer, and their position enables them to elude the inexperienced operator One of the glands of the group often lies in front of the axillary vein, in a prolongation of the axillary fat which passes upwards across the vein towards the tip of the coracoid process

The afferent vessels mostly come from the other axillary glands which converge to the subclavicular glands They also receive a vessel running along the cephalic vein, and a branch accompanying the acromio-thoracic artery, which comes from the breast through the great pectoral (Rotter) This vessel may bring about the infection of the apical glands in breast cancer before the lower axillary glands are invaded—an important surgical fact The efferents of the subclavicular glands after forming a plexus unite into a single trunk, which runs in front of the subclavian vein, behind the subclavius muscle, to terminate in the great veins in the angle where the internal jugular joins the subclavian vein It is important to notice that nearly always one of the efferents of the subclavicular group passes into a gland in the subclavian triangle, and this is one route by which the supraclavicular glands are attacked

Internal mammary glands (*syn*, retrosternal parasternal sternal anterior mediastinal glands) —The internal mammary glands lie along the artery of the same name, half an inch outside the margin of the sternum In front of them are the anterior intercostal fascia and the internal intercostal muscles behind them lie the internal mammary artery and vein, and the pleura which in this situation is very thin The gland in the third space has behind it the triangularis sterni

Mr Philip Stibbe re-investigated the anatomy of these glands He found four or five on each side, one each in the first, second, third and fifth or sixth spaces

In breast cancer they possess much surgical importance They receive, along the course of the perforating branches of the internal mammary artery, small tributaries from the pectoral lymphatic plexus, which, of course, is connected directly with the breast

The efferent vessels of this chain of glands unite into a single trunk which empties itself into the anterior surface of the junction of the internal jugular and subclavian veins It is, however, important to notice that frequently one of the efferents is tributary to a gland in the subclavian triangle lying just superficial to the subclavian artery, and that gland infection of the neck may arise by this route

MAMMARY CANCER

Evolution of the treatment of breast cancer.—A very brief history of opinion and practice in the treatment of breast cancer may have some practical value In 1867 Charles Moore at the Middlesex Hospital, stressing the local origin of cancer, insisted upon the removal of the whole breast and of unsound adjoining structures, including the axillary

glands In 1882 Mitchell Banks gave similar advice, and insisted on the routine removal of the axillary glands, as did also Samuel Gross in 1888 Sir Harold Stiles in 1892 demanded the fashioning of extensive skin flaps so that the outlying portions of the breast could be reached and the organ completely removed He found that cancerous lymphatics are frequently present throughout the breast, and his teaching was followed by Sir Watson Cheyne (1893)

W S Halsted (1894) was the first to advocate routine removal of the sternal portion of the great pectoral muscle In some other respects his operation was inferior to that of Stiles and Cheyne, removing an unnecessary amount of skin, but not fashioning skin flaps, so that the removal of the subjacent deep fascia was inadequate It was Halsted who converted world opinion to the necessity of a wide monobloc operation, and any operation of a radical nature is often loosely called by his name

In 1906 I showed the danger of invasion of the abdomen through the epigastric deep fascia and advised the removal of the upper part of the anterior layer of the rectus sheath Abdominal recurrence, formerly common, is now in consequence rare I also showed that the disease when it reaches the limits of the breast, continues to spread by permeation in the lymphatic plexus of the deep fascia, and advocated the removal of a circle of deep fascia, 10–12 in in diameter and centred upon the primary growth, as perhaps the most important step of the operation My operation has proved most satisfactory in preventing local recurrence, which is now very unusual

Late recurrences at the edge of the sternum and in the supraclavicular glands remained frequent I traced them to invasion of the internal mammary chain of glands before operation * Since 1920 I have introduced radium tubes at the time of operation to deal with this danger, and "parasternal" recurrences have since almost disappeared from my practice Radiologists who are not anatomists have failed to realize that radium tubes can with certainty be brought into close proximity to the internal mammary glands, and have criticized the method as a ' hit or miss" one, or as failing to secure "a uniform field of radiation, but it has been justified by a 10 per cent reduction of three year recurrences

I note with some concern that local irradiation of the internal mammary glands at the time of operation has not been generally adopted It is a rational step, based on a combination of clinical and pathological evidence I am not convinced that external radiation can effectively replace it Adair and Stewart, at the Memorial Hospital in New York, subjected 89 cases of operable breast cancer to radiation by a 4 g radium pack at a distance of 6 cm, using five ports and giving 20,000 to 44,000 m c hr per port In spite of this vigorous treatment, on subsequent operation viable cancer cells were found in the breast in 28 per cent and in the glands in 73 per cent. of cases †

* *Surg, Gyn., Obst.*, Dec., 1927, xlv 721

† *Ann of Surg.*, 1935 cii, 254

Buried-tube radiation —In 1924 Mr Geoffrey Keynes began to employ buried radium as a complete substitute for operation, choosing at first fifty advanced or inoperable cases Six of these patients are alive nearly ten years after treatment, and five are free from recurrence Many of them lived for periods up to eight years without external signs of disease For this class of case Keynes' method constituted a great advance

In 1928 I pointed out the difficulty of ensuring adequate radiation of such a large volume of tissue as is represented by an adipose breast together with the whole contents of the axilla I concluded that "operation still remains a necessity to remove the bulk of the disease and to reduce the problem of the radiologist to manageable proportions For the present at any rate, surgery and radiology must be colleagues, not competitors To use either means alone is to fight a dangerous antagonist with only one hand"

Restricted operation combined with buried tube radiation —The disadvantages of buried radium alone have been described by Mr Keynes in a recent paper *

> "The patients were carefully observed and in due course a certain number of failures were noted These failures were either shown by incomplete disappearance of the primary tumour or by the appearance of recurrent nodules in the breast or in the skin In a number of patients these residual tumours were removed and examined nine months or more after the irradiation It was then found that in 50 per cent no discoverable cancer remained the tumour consisting entirely of fibrous tissue In the other 50 per cent there was evidence of active cancer This result led to a reconsideration of the procedure, and it was realized that the failures might reasonably be attached to the physical limitations of radium needles The penetrating power of the rays is strictly limited and many of the tumours were too thick and bulky for the gamma rays to penetrate them effectively, so that the cancer cells at the centre or at the surface did not receive a lethal dose The bulk of the tissues to be irradiated did seem to be a serious obstacle unless the dosage of radium were to be greatly increased, and to this there were other objections"

Moved by these considerations Mr Keynes now more frequently removes either the tumour or the breast before irradiation according to circumstances but without removing the pectoral muscles or dissecting the axilla, following the policy initiated by Mr Duncan Fitzwilliams, and securing "a minimum of mutilation" He claims that axillary recurrence never takes place, and summarizes his policy as follows —

1 Local removal of tumour if it is large or the diagnosis is uncertain, followed by radium

* Brit Med Journ Oct. 2, 1937 ii 643

2 Local removal of the breast if the tumour is very bulky followed by radium

3 Never dissect the axilla

4 Radium by itself may be used (a) if the tumour is of moderate size and the diagnosis certain on clinical grounds (b) if the patient refuses operation

From the statistics be gives based on 250 cases the results of Keynes treatment in operable cases appear within the limits of error to be neither better nor worse than the results of operation alone

Keynes frankly states the disadvantages of bis present methods 1 The results are difficult to interpret since residual lumps which may or may not contain living cancer cells are frequently found 2 Post irradiation fibrosis may appear as late as two years after treatment in the positions where irradiation has been most intense Fibrous lumps may appear on the inner wall of the axilla, and may arouse suspicion of recurrence 3 There is an increased liability to neuralgia or rheumatic pains in the treated area 4 Post irradiation fibrosis of the pectorals may produce limitation of movement

It thus appears that the originator of the buried radium alone policy for breast cancer has receded somewhat from the position he originally adopted with regard to radium as the sole remedy for breast cancer

According to Todd and Dawson* the method has been almost completely given up in Edinburgh Of 32 cases treated from 1930 to 1932 only five survived five years of which four were stage I without palpable axillary glands A consensus of opinion seems now within sight that a combination of operation with simultaneous radium tube radiation is best for the average case of breast cancer Difference of opinion still remains as to the relative scope of these two elements While some surgeons would trust to radium for the outlying extensions of the tumour in and beyond the breast and in the axilla others myself among them regard the present tendency to experimental restriction of the operation as dangerous Admitting that an operation is necessary the present radical operation is so safe and so free from discomforts and sequelæ that there seems little reason to modify it Mr Keynes stresses the mutilation it produces and the immediate risk to life which he places at 3 per cent He speaks of brawny arm as a not infrequent sequela and thinks that the operation sometimes produces widespread local dissemination

His impressions are not in accordance with the facts as I have found them in my own experience The mortality of the operation is a fraction of 1 per cent pain and shock after the operation are absent or slight and a brawny arm resulting from the operation is hardly ever seen It only occurs in cases with supraclavicular recurrence It may be questioned whether on the average a partial removal of the breast gives a better cosmetic result than complete mastectomy

* E and S. Livingstone Edinburgh *Cancer* 1937 p. 39

Restriction of movement from fibrosis of the pectoral muscles is not rare after radiation, so that functionally the radical operation probably gives a better result A puckered breast can hardly be beautiful, and radiation always causes fibrosis Psychologically the long period of waiting for the lump to disappear, and doubts as to the nature of any residual lump, impose a strain on the patient and her medical advisers which may prove in the long run much greater than that of a radical operation

It is at present too soon to estimate the value of the method of local excision plus implanted radium, and personally I do not feel able to recommend it with confidence

On the whole I conclude that the standard treatment for breast cancer should be radical operation with implanted radium in the supraclavicular and along the internal mammary glands This rule applies especially to —

1 Patients with voluminous breasts in whom unless the growth is unusually early the mere volume of tissue to be radiated may be an insuperable difficulty
2 Left-sided breast cancer in patients with cardiac weakness or disease
3 Patients with operable but ulcerated and septic growths Extensive sloughing may follow the use of radium in such cases

In a large percentage of cases excluding those just mentioned, the patient may be offered a choice between (a) radical operation with parasternal buried radium (b) limited excision with buried radium, and (c) buried radium alone My view is that the first alternative offers a greater measure of security and a more immediate relief from anxiety, at the cost of a very small operative risk

In certain cases, I would definitely advise implanted radium in preference to operation If the growth is infiltrating the intercostals or if the axillary glands are fixed, implanted radium may, nevertheless, give valuable and prolonged palliation It may be combined with limited diathermic removal of an ulcerated growth

Also, in small growths starting at the periphery of the breast, and often also in carcinoma of the male breast, radium implantation seems to hold the advantage over operation, owing to the difficulty of centring the operation on the primary growth and, in the male, to the difficulty of fashioning skin flaps

For the average case, the plan to which I still adhere is to remove the accessible portions of the disease by radical operation, and at the same time to deal with possible intra-thoracic extensions by buried radium From 1927 until 1939 I partly did the operation by the diathermy needle hoping to eliminate shock, lessen bleeding, seal the channels of absorption, and remove the risk of implantation The peripheral fringe of the circle of deep fascia need not be actually removed provided the diathermy needle sears it, so that the technique of the operation is simplified and its extent diminished Defence regulations, making

difficult the use of diathermy apparatus have since led me to return to the scalpel I have failed to detect any long range inferiority in results compared with diathermy and convalescence after the knife operation appears to be smoother and perhaps more rapid The advantages of diathermy seem to be largely theoretical and I would now only advocate it in special cases e g ulcerated growths

Mode of spread —It is evidently of great importance to surgeons to know in detail how breast cancer spreads The statistics of diverse methods of operation are an uncertain guide to the ideal method of operation Here as in other medical matters statistics can only occupy a secondary place as supplying confirmatory evidence of con clusions already reached hy pathological research

Some years ago I tried to rationalize operative methods in breast cancer by a careful study of the phenomena of dissemination The pioneer work of Stiles and Heidenhain had been restricted to the spread of cancer within the limits of the breast itself and did not produce even in the minds of those authors themselves any doubt as to the theory of dissemination then current namely the embolic or water carriage theory The cancer cells set loose from the primary growth were imagined to be swept along like driftwood by the lymph or the blood stream until arrested in some narrow channel There can of course be no doubt that such lymph emboli are the agents which infect the axillary glands in an early stage of the disease But a study of the other secondary deposits accessible to observation viz those in the skin and bones shows that these deposits beginning near the primary growth spread in a centrifugal manner from it This is illustrated for bone depôsits in the following table —

FREQUENCY OF CANCEROUS DEPOSIT OR SPONTANEOUS FRACTURE IN 829 CASES OF MAMMARY CANCER AT THE MIDDLESEX HOSPITAL

	BONE	NO OF CASES	PERCENTAGE OF TOTAL
Bones lying wholly or partially within the area liable to subcutaneous nodules	Sternum	30	9 0
	Ribs	28	8 0
	Clavicle	5	1 5
	Spine	12	3 6
	Cranial bones	9	2 7
	Scapula*	1	0 3
	Femur	14	4 2
	Os innominatum*	0	0 0
	Humerus	9	2 7
Bones lying beyond the area liable to subcutaneous nodules	Radius	0	0 0
	Ulna	0	0 0
	Tibia	1†	0 3
	Fibula	0	0 0
	Patella	1†	0 3
	Bones of hand	1	0 3
	Bones of foot	0	0 0

* This bone owing to its shape is not much liable to spontaneous fracture and rarely comes under observation at an autopsy

† Knee ankylosed, femur affected in its whole length, with extension of growth to patella and head of tibia.

Subcutaneous nodules are found to obey the same law They appear first near the primary growth, and spread from it in a larger and larger circle, but this circle hardly ever spreads below the elbow or below the knee, because the patient dies before it has been able to reach the fore-arm and the leg Yet it is in the distal ends of the limbs, above all other places, that the effects of embolism might be anticipated

These exceptional cases of very extensive centrifugal spread show on a large scale what is occurring to a lesser extent in every case of breast cancer If long centrifugal strips of the skin and subcutaneous tissues are taken in a direction radiating from the primary growth, there will be found in them, at points near the growth isolated secondary nodules Farther out, at a varying distance up to 10 in from the primary growth,

Fig 328 —Permeation of the pectoral fascia in breast cancer before the breast has become adherent to the fascia The axillary glands were free from growth ×85

A Loose areolar tissue between the breast and the pectoral fascia B Pectoral fascia showing darkly-stained permeated lymphatic vessels C Pectoral muscle

a narrow and elusive zone a few millimetres wide will be found on the deep fascia where its lymphatic vessels are choked by cancer cells Beyond this zone only normal tissues will be seen The zone occurs in each of the radiating strips, and is a section of a large circle which constitutes the true growing edge of the disease This *microscopic growing edge* may be found at any distance up to 2 ft from the primary growth, and its detection is the foundation-stone of the permeation theory of dissemination By permeation is understood the choking up of the lymph-vessels by the growth in continuity of cancer-cells along them

The facts can only be explained as follows The immense prolifera-tive pressure of the epithelium at the primary focus forces cancer-cells into the lymphatic vessels, along which they grow in continuous lines Reaching the lymphatic plexus to which the breast in the first instance

drains namely the fascial plexus lying upon the great pectoral muscle permeation involves a larger and larger circular area of this plexus filling up its channels with lines of cancer cells and sending offshoots into the adjoining muscular and cutaneous layers Sooner or later carcinoma cells are thus brought into the serous cavities and rapid visceral dissemination ends the patient s life

Since the existence of fascial lymphatic vessels has been recently denied I here insert a photograph (Fig 328) of permeated lymphatics in the pectoral fascia

It may be objected that if permeation were so important a process it could not so long have escaped observation The answer is that it is a fugitive process the evidence of which is soon obliterated Permeation of the lymphatic is followed by the curative process to which I have applied the name of perilymphatic fibrosis which obliterates the lymphatic and destroys the cancer cells contained in it The fibrous lymphatic is no longer a permeable vessel but merely an unrecognizable thread of solid fibrous tissue Permeation in its continuous slow centrifugal spread leaves behind it only an almost undetectable network of fibrosed lymphatics or an occasional isolated secondary nodule where the protective process has failed Breast cancer may be conceived of as a gigantic ringworm of permeated lymphatics situated in the plane of the deep fascia

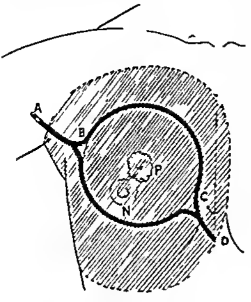

Fig 329 —Area of fascia removed in Handley s operation for breast cancer

N nipple P primary growth.

(*Handley's Cancer of the Breast"*)

The shaded area is the area of deep fascia which requires removal. The primary growth is, in this case situated just above and internal to the nipple as marked It should always be at the central point of the area of deep fascia removed.

Operative principles —The main operative principles deduced from the permeation theory are these

1 The area which needs widest removal is that in which the growing edge is situated viz the deep fascia for in this layer is found the lymphatic plexus which forms a highway for the spread of the disease beyond the limits of the breast

2 The area of deep fascia removed must be circular in outline since permeation spreads with approximate equality in all directions from the primary growth (Fig 329)

3 The primary growth must always be the centre of the area of fascia removed

4 The skin and muscles being secondarily involved over a smaller area and less widely than the fascia, the removal of a smaller area of these tissues will suffice The removal of the axillary lymphatic glands in continuity with the primary growth is, of course, essential, since emboli of cancer-cells reach them early along the trunk lymphatics

A specially important mode of invasion of the viscera is that which I have described as **epigastric invasion.** It might naturally be expected that permeation would always reach the pleural cavity immediately underlying the primary growth before it penetrated to the remoter peritoneal cavity But this is not the case After death, secondary deposits are found in the abdomen alone in 12 per cent of all cases of breast cancer, the thoracic cavity remaining entirely free from metastasis The embolic theory fails to account satisfactorily for the failure of the cancerous particles which must presumably have passed through the pulmonary circulation to infect the lungs on their way to the abdomen

These cases of purely abdominal dissemination are usually caused by the direct infiltration of the abdominal parietes in the epigastric region, just below the ensiform cartilage This point is the Achilles' heel in the defences of the body cavity against breast cancer; for, when *the circle of fascial permeation has spread about an inch beyond* the circumference of the mamma, the cancer-filled lymphatics of the fascial plexus in the middle line, just below the ensiform cartilage, are separated from the subperitoneal fat only by a single thin layer of fibrous tissue, the linea alba I have traced all the stages in the invasion of the abdominal cavity at this point, and have shown how the cancer further spreads from the epigastric parietal peritoneum to the adjacent convex surface of the liver, or to the portal glands, and how cancer-cells may fall through the peritoneal cavity and give rise to pelvic metastases

In the operation for breast cancer, no particular attention has hitherto been paid to the epigastric region The operation, while safeguarding the thoracic cavity from invasion, ignored the danger of abdominal invasion Yet, as I have shown the latter may be *the earlier and consequently the more important event* In the epigastric region the fascial lymphatic plexus lies upon the anterior layer of the rectus sheath, which must be removed in so far as it comes within the limits of the presumably infected fascial circle

Contra-indications to operation.—Operation should be refused—

(*a*) When the primary growth has attacked the bony thorax
(*b*) In the presence of cancer *en cuirasse* or of subcutaneous nodules or skin infiltration situated more than 2 or 3 in from the primary growth, or of extension to the opposite breast or axilla
(*c*) If there is a fixed mass of growth in the axilla evidently adherent to its walls
(*d*) If there is œdema of the arm

(e) If the supraclavicular glands are enlarged hard and fixed
(f) If there is evidence of visceral or bone metastases
(g) If there is incurable constitutional disease tuberculosis or diabetes for example likely to be fatal within a short period or to lead to a postoperative fatality
(h) If the growth is of the acute fulminating type
(i) In old age if the growth is of the hard chronic variety

In the absence of signs of internal dissemination certain cases which have passed the limit of operability may still be amenable to treatment by buried radium A combination of restricted ablation and radiation may be advisable in massive ulcerated and infected growths with limited dissemination Such cases are not suitable for radium alone in view of the extensive sloughing that would follow

Examination—A complete medical examination of the patient should be made before operating The spine should be examined for angular curvature Seats of pain e g the trochanters should receive especially careful attention and an X ray examination of the thorax is advisable

Examination for secondary deposits—A careful examination of the epigastric parietes for subcutaneous nodules—a sure indication that infection of the abdomen has already taken place—should be made especially if tenderness or pain is complained of in this region Palpation of the liver must not be omitted Above all it must not be forgotten that the first sign of epigastric invasion may be found in the pelvis from the gravitation into it of cancerous particles A recto vaginal examination must be routine and the presence of pelvic pain enlargement of the ovaries or induration in the recto vaginal pouch should raise a grave suspicion that the disease is inoperable It should be noted that early secondary cancer of the pelvis does not fix the uterus

Atrophic scirrhus demands especially careful examination for in spite of the quiescence of the primary growth dissemination may have progressed far But if no such insidious spread is found operation should not be refused Old age is no contra indication to operation in itself but demands some restriction in its scope I have operated on a patient over 80 who died more than ten years later of pneumonia without recurrence Cases presenting enlarged supraclavicular glands if the glands are still movable should not be denied operation Though in such cases optimism is misplaced freedom from recurrence for periods up to ten years or more may be secured if excision of the glands is accompanied by radium treatment The glands can usually be removed at the same time as the breast Among 76 cases recorded by Halsted in which three years after operation no recurrence had taken place there were 9 in which cancerous supraclavicular glands had been removed

Palliative operations—It is often justifiable to operate in cases where cure seems beyond the range of hope Such operations are

directed (a) to prolong the active and useful period of life and postpone disability (b) to suppress the external manifestations of the disease and relieve the patient of the distress and pain associated with an ulcerated tumour They are to be recommended only where it seems reasonably probable that no external recurrence will take place before internal deposits the seeds of which are probably already present will end the patient s days in a comparatively merciful way With present day radiological methods the scope of such palliative operations is much widened and an additional period of two to five years of activity and freedom from pain may be secured A patient with extension to the opposite breast and axilla for whom I performed a bilateral operation removing both breasts and the axillary glands of both sides in one continuous mass did active work as a laundress for two years afterwards Another patient the mother of a young family was refused operation by the surgeon whom she first consulted She accepted my offer of a sporting chance and subsequently did five years active house work before she succumbed to thoracic deposits There was no external recurrence

Technical Variations in the Mode of Operation

It is obvious that there are many different ways of attaining the object defined earlier (p 557) as the removal intact of the permeated area of lymphatics which surrounds the primary growth and of the embolically invaded glands Any variation of method which does not violate the canons of pathology may be adopted in order to secure some particular advantage or merely at the personal preference of the operator

Methods in which dissection of the axilla precedes removal of the breast.—There is something to be said in favour of clearing the axilla before the breast is ablated As Gross pointed out the axillary tissues may be found so involved in growth that their removal is impracticable This is discovered at once before the operator has gone too far to turn back It is in such cases that the method finds its best application They are usually recognizable beforehand as doubtfully operable cases If the axillary glands are partly fixed or unusually large the axilla should be explored as the first step of the operation and the Rodman method may be conveniently adopted Rodman believed that by early division of the axillary lymphatics the risk of expressing cancer-cells into adjacent and even possibly remote tissues could be avoided It seems however just as likely that early division of the lymphatic trunks will increase the risk of implantation of cancer cells in the wound Another advantage claimed for the operation is that the breast is left as a warm covering for the thorax until the operation is nearly complete This end can be just as well secured by relays of hot towels It was further claimed by Rodman that hæmorrhage is very much less when the branches of the axillary artery are exposed early and ligated at their origin This may be true to some extent but the most troublesome source

of bleeding namely the perforating branches of the internal mammary artery is left to be dealt with later Personally believing that the removal of the infected circle of deep fascia can be more certainly and deliberately done before the axilla is opened and that this is the most important step of the operation I have not adopted any of the axilla first methods I have not found that the breast first method involves serious bleeding unless the mistake is made of using ether as the anæsthetic

Rodman's operation—The axilla first method is said to have been first practised by Meyer It is advocated also by Kocher and by Rodman As the method constitutes an important technical variation in operative procedure and violates none of the canons of pathology I shall quote a part of the late Prof Rodman's account of his operation *

> A straight incision is made beginning 1 in below the clavicle two finger breadths from and parallel with the sulcus between the deltoid and the clavicular portion of the pectoralis major It extends well below the free edge of the pectoralis major muscle and in extent will usually be from 5 to 6 inches or more according to the stature of the subject and the size of the breast It is rapidly carried down through skin and superficial fascia to the fascia covering the great pectoral muscle No hæmorrhage of consequence is encountered thus far I prefer to place this incision not too close to the arm for in my judgment incisions extending on to the arm result in cicatrices which often seriously interfere with the future usefulness and less frequently cause œdema of the limb
>
> The index finger of the left hand is now introduced beneath the lower border of the tendon of the great pectoral muscle and made to emerge above its upper border or in the interval between the costal and clavicular portions if one wishes to remove only the costal origin of the muscle and division of the tendon is effected at or near its insertion into the humerus This may be facilitated by dissecting up the external flap slightly and using retractors I myself see no reason for removing the clavicular portion in the average case and therefore leave it unless the growth is peripheral and in the upper hemisphere Then unquestionably the entire muscle should be sacrificed Only a slight dissection will be necessary to discover the lower edge of the tendon of the pectoralis minor This should be clearly identified and separated from the fascia covering the tendon and below it Otherwise the long thoracic artery which runs in the fascia parallel with and just below the tendon may easily be wounded
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> The index finger is now introduced underneath the muscle and made to emerge at its upper border Lifting up the

* "Diseases of the Breast," Philadelphia, 1908.

muscle, the tendon is made tense and prominent, so that it can readily be seen that no other tissues are included with the tendon The acromio thoracic artery runs just above and parallel with this tendon, and, being a branch of considerable size might cause some little embarrassment if it were cut at this stage of the operation Therefore we have the acromio-thoracic artery parallel with and just above the upper border of the minor pectoral tendon the long thoracic parallel with and just below its lower border Both can easily be avoided if care is taken I have never as yet wounded either vessel nor is there excuse for doing so The tendon is divided at its insertion into the coracoid process Both muscles retract inwards as soon as their respective tendons are severed This at once uncovers the axilla and makes its subsequent thorough dissection easy The costo-coracoid membrane is now opened and largely sacrificed which gives easy access to the sub clavicular fat at the apex of the axilla—in the space of Mohren heim In removing a part of the costo coracoid membrane, the cephalic vein at the upper and outer aspect of the wound must not be wounded There is also in the fascia a branch of the acromio thoracic which with its accompanying vein, should be clamped and tied A nerve supplying the pectoral muscle may as well be sacrificed now as it necessarily must be later on when the muscles are removed

"The dissection is begun at the apex of the axilla and must be carefully conducted lest injury be done either to the axillary vein or the acromio thoracic artery It should be from above downward, though this is perhaps somewhat more difficult than making the dissection from below upward

' In the removal of the fat and fascia in the upper third of the axilla the finger, covered by several thicknesses of gauze, will be all that is necessary Instruments are rather dangerous unless used most cautiously Moreover, they are unnecessary

"I now carefully make an incision through the fascia to the outer side of the axillary vessels simply to start the dissection from without inward This is made to the extent of the lower two thirds of the axilla and not in the upper third, where it is dangerous to cut I continue the dissection largely with gauze, but Allis's or Mayo's blunt dissectors may be used freely and are most helpful Occasionally a cut with scissors or a sharp knife facilitates the dissection The instrument of Charles H Mayo is more than a blunt dissector, for it can be used also as a scissors, and is most valuable in economizing time, making a change of instruments unnecessary

"As the sheath and fat are removed from the vessels we come down upon the acromial long and alar thoracic branches, and the subscapular branch of the axillary artery, in the order named, from above downwards, which, with their accompanying

veins, are to be carefully clamped in two places and divided between The proximal ends are ligated In this way the subsequent hæmorrhage is materially lessened, in fact, it is surprising how little blood will be lost during so prolonged and extensive a surgical procedure

"The enlarged lymphatic glands will usually be found at the base of the axilla between the latissimus dorsi, teres major, and subscapularis muscles posteriorly, the serratus magnus internally, and inferior to a line formerly indicated by the situation of the lower border of the pectoralis minor The midaxillary and subclavian glands may, however, be infected All such enlarged glands and surrounding fat should be carefully dissected from the several muscles, and, to do this best, the fascia covering the muscles should be sacrificed In fact, so thorough should be the axillary dissection that nothing is left on the inner aspect save the posterior thoracic or nerve of Bell, on the posterior aspect only the long subscapular nerve, and superiorly, possibly the superior thoracic artery, if it arises as an independent branch high up on the first portion of the axillary In such circumstances it is impossible, in my judgment to reach it with safety It is so deeply placed that there is great danger of doing serious damage to the vein and artery, the former particularly, if an attempt is made to secure the vessel at its root It is a small branch, and negligible as far as subsequent hæmorrhage is concerned Moreover, it not infrequently arises conjointly with the acromio-thoracic, and in such cases is easily secured with the other vessel

A thorough dissection of the axilla can usually be finished in twenty minutes, and is entirely accomplished through the single straight incision It should be invariably from above downward, without inward, and *en masse* A piecemeal extirpation is not to be considered Patience, a good light, and working with blunt dissectors, all ensure a safe and reasonably speedy dissection of the axilla As we have said sharp instruments are not to be used at the apex of the axilla, but may materially facilitate the dissection at its base Accidental injuries to the vein are not common and, when occurring, are, if practicable, to be treated by lateral ligature or suture"

Rodman goes on to describe the removal of the breast, which does not differ materially from accepted methods The full account can be read in his book

Handley's Method of Operation

The operation now to be described appears applicable to almost any case that presents itself with clinical signs of mammary carcinoma Even if the case be an early one without obvious enlargement of the axillary glands the scope of the operation should not be restricted if

the patient is vigorous But in feeble old people a more limited operation should in any case be practised to minimize the immediate risk

My method has been arrived at by a critical study of the procedures of various operators in the light of my own studies of dissemination The operation first described by Stiles and Cheyne has stood this test better than any other and with some modifications and with the addition of routine removal of most of the great pectoral (Halsted) forms the basis of the method

The operation is not put forward as the only method of removing a breast cancer Any number of technical variations are possible but these should all be tested by the pathological criteria now available

Preparation of the patient—A purgative preferably an ounce of castor oil should be given thirty six hours before the operation A purgative the night before the operation is undesirable as tending to deplete the patient s fluids If the patient is tired or nervous or if the heart is flabby a few days rest in bed and small doses of strychnine are advisable

Finzi recommends pre operative X radiation as tending to increase the resistance to growth Personally I would not defer an operation for this but if for any reason a short postponement is necessary it may be borne in mind

The axilla should be shaved the night before operation and as a septic area it should be scrubbed with ether soap and then with acetone and iodine Scrubbing of the breast itself is to be avoided as tending to massage cancer cells along its lymphatics The breast area is simply painted with iodine or mercurochrome solution the night before and covered up with sterile gauze until the time of operation when it is again painted The area sterilized should in every direction considerably overlap the area of operation

During the operation the arm should be held by an assistant abducted to rather more than a right angle It should not be stretched upwards for forcible elevation may cause subsequent neuralgia from stretching of the brachial plexus I have even seen one case where brachial palsy was thus produced

The patient should lie close to the edge of the table on the side of the operator The assistant stands on the opposite side

Choice of anæsthetic—Ether even when it is given without cyanosis causes an undesirable amount of bleeding Personally I still prefer C E mixture or for old people pure chloroform but of late I have been much impressed by the psychological advantages of one of the intravenous barbituric acid compounds as a preliminary The use of oxygen seems to be advantageous Minimal bleeding is secured with pure chloroform provided free oxygenation is maintained Anæsthesia should be light with absolutely unimpeded respiration Ether may be used during the operation if signs of shock supervene Mild temporary shock is not unusual during the stripping of the breast from the chest An injection of morphia gr $\frac{1}{4}$ and atropine gr $\frac{1}{100}$ or of omnopon

gr ⅙ may with advantage be given an hour before operation. Frequently the pulse at the end of the operation does not exceed 80 per minute if chill is avoided.

Centring of the operation.—The centre of the growth, not necessarily the nipple, must be taken as the central point of the operation. The operator is not doing an "amputation of the breast"—his aim, it may be repeated, is the removal in one piece, enclosed in a sheath

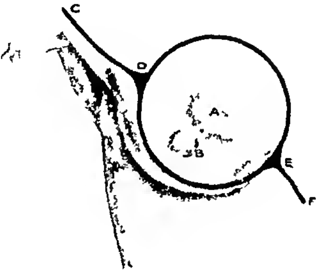

Fig. 330.—Handley's operation for breast cancer. The incision.

D E is the possibly infected area of skin, 4–5 in. in diameter, which requires ablation. It is centred upon the growth A, not upon the nipple B. D C is the incision of access to the axilla; it has a slight convexity backwards, and should lie in the vault of the axilla just under cover of the lower edge of the great pectoral muscle. E F is the incision of access to the epigastric region. The point F lies just beneath the ensiform cartilage. Redundant corners of skin may be trimmed off at the end of the operation.

(N.B. In the figure the incision CD is represented too far forward.)

of normal tissue, of (1) the permeated area of the lymphatic system which surrounds the primary growth, and (2) the lymphatic glands which may have been embolically invaded by the disease. The permeated area of the lymphatic system may extend considerably beyond the limits of the breast.

Skin incision.—The skin incision is only just deep enough to open up the subcutaneous fat without extending through it into the neighbourhood of the deep fascia. It consists of three parts.

(1) A *ring incision*, as first practised by Mitchell Banks, 4 or 5 in. in diameter, accurately centred on the growth and surrounding it at

a safe distance, slightly tailing off into (2) above and into (3) below It is a good practice before beginning the operation to mark out by a scratch mark the circle of dangerous skin which requires removal

(2) A *curvilinear incision* giving access to the axilla The axilla is opened by turning forward a rudimentary flap consisting of skin and a thin layer of subcutaneous fat, whose base lies along the anterior axillary fold The axillary incision begins at the lower edge of the great pectoral, close to its insertion It ends, also, at the lower edge of the great pectoral, by joining the annular incision (1) It crosses the base of the axilla, and its convexity reaches back about an inch towards the axillary vault It affords perfect access to the axilla, and good drainage afterwards Incisions following the lower edge of the great pectoral muscle are likely to result in a bridle scar which limits the movements of the arm

(3) A *linear incision* coming off from the lower and inner part of the annular incision and passing downwards for about 2 in towards the tip of the ensiform cartilage Its object is to give access for the removal of the deep fascia over the upper part of the abdominal wall Without it this important step in the operation cannot be properly carried out (Fig 330)

Elevation of the skin-flaps.—The skin flaps are next undermined in the midplane of the subcutaneous fat (Fig 331), until a circular area of the deeper subcutaneous fat, 10 to 12 in in diameter, with the primary growth at its centre, is exposed The exact anatomical limits of this dissection will of course, vary with the situation of the growth in the breast The assistant retracts the skin flaps as they are formed, and subsequently keeps them carefully wrapped in hot towels frequently renewed Neglect of this precaution is likely to be followed by severe shock, and later by ulceration of the edges of the flaps

At this period of the operation no attempt should be made to apply artery forceps to every small bleeding point Spouting vessels in the deep surface of the skin flap should be clamped but bleeding from the exposed surface of subcutaneous fat is sufficiently checked by the pressure of large flat swabs for nearly all the exposed vessels will again be divided at a deeper level It is often useful to tuck sponges beneath the flaps as these are formed

Delimitation of the area of deep fascia to be removed.—An annular incision marking out the 10 in circle of deep fascia to be removed, is now carried down to the muscles through the deeper subcutaneous fat close to the base of the skin flaps which are meanwhile strongly retracted by the assistant

Elevation of deep fascia from the underlying muscles.—The circular area of deeper subcutaneous fat and deep fascia, in which lies embedded the presumably permeated area of the fascial lymphatic plexus, is now dissected from the subjacent muscles for some distance from its circumference towards its centre, so as to form a wide marginal

fringe of the main mass consisting of breast, pectoral muscles and axillary contents which is subsequently to be removed. The fringe of deep fascia is to be raised up all round the field of operation until

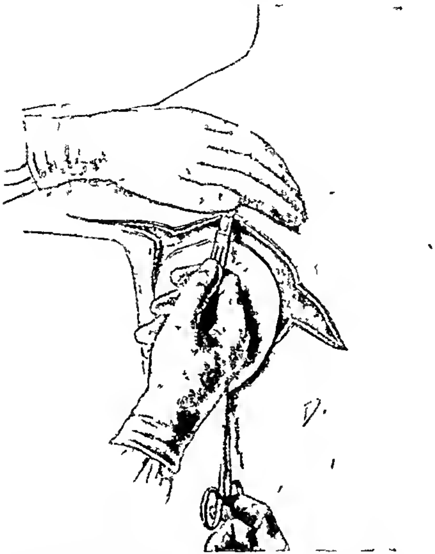

Fig. 331.—Undermining of skin flaps by subcutaneous transfixion

An assistant meanwhile with a pair of artery forceps pulls the breast in a direction indicated at each moment by the direction of the handle of the operator's knife. The knife keeps to the plane of the subcutaneous fat. In thin subjects, or if the operator is inexpert, the flaps should be raised by ordinary dissection.

the knife reaches either the margin of the great pectoral muscle, the margin of the axillary outlet, or the edge of the breast, as the case may be (Fig. 332).

The amount of dissection required varies in different parts of the field of operation. At the upper limit of the field the fascia must be dissected off the clavicular portion of the great pectoral if it has

been decided to retain the clavicular fibres of this muscle otherwise in this region the fascia will come away with the great pectoral when that muscle is divided at its clavicular origin and very little freeing of it will be requisite Towards the middle line it will usually require dissecting up from the sternum and in growths of the inner margin

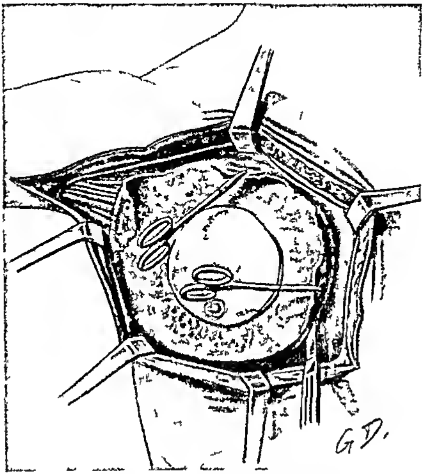

Fig 337 —Elevation of deep fascia

The thin skin flaps have been raised so as to expose a circle of the deeper subcutaneous fat 10 to 12 in in diameter The circle has been circumscribed by a ring incision passing down through the deep fascia The included area of deep fascia containing the growing edge of the disease is now being raised all round from the muscles

of the breast from the inner margin of the opposite great pectoral muscle In such cases the surgeon may divide and must secure the perforating branches of the internal mammary artery on the side opposite to the growth The corresponding perforating branches on the same side as the growth are divided later during the detachment of the great pectoral

At the lower limit of the field of operation a 10 in circle of deep fascia with the growth at its centre will usually extend well down

over the epigastric region of the abdomen In this part of the field the anterior layer of the rectus sheath, on both sides of the middle line, should be raised up and removed with the deep fascia To accomplish this, the linea alba must be split from below upwards in the coronal plane In the epigastric region wide and careful removal of the deep fascia is imperative, so as to prevent the access of cancer-cells to the peritoneal cavity In this part of the field, numerous small blood-vessels emerging from the rectus muscle will probably need attention

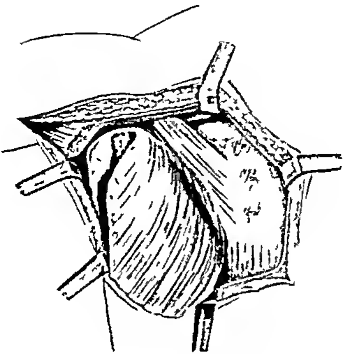

Fig 333 —Reflection of pectoralis major

The deep fascia and the upper part of the anterior layer of the rectus sheath have been raised as far as the edges of the great pectoral. This muscle has been divided at its origins and its insertion, the perforating intercostals have been tied, and the breast turned over toward the axilla.

Towards the outer side of the field, the fascia must be dissected up from over the anterior edge of the latissimus dorsi and from the serratus magnus Higher up, especially if the growth lies in the outer portion of the breast the fascia over the inner margin of the deltoid muscle and about the posterior margin of the axillary outlet must be raised if it falls within the circle marked out for removal although the requisite dissection is difficult and tedious A method for overcoming this difficulty is described on p 623

Division of muscles.—If the growth is an early one, or is situated low down in the breast, it is probably safe to leave the clavicular part of the pectoralis major With this exception the whole of the great pectoral needs removal (Fig 333) It is first split close to its

clavicular attachment a finger is inserted beneath the muscle from above so as to put its fibres on the stretch and its chondral and sternal attachments are rapidly divided from above downwards close to their origin

It is best to scrape through rather than cut the origin of the great pectoral from the sternum and costal cartilages In this way the perforating intercostal branches are seen and caught in turn before they are divided Much bleeding is thus saved and the risk of trouble

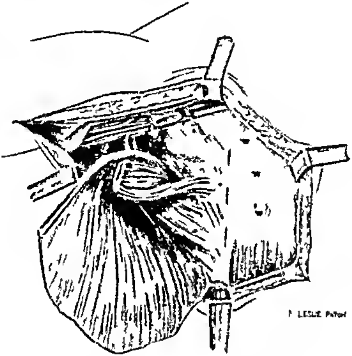

Fig 334 —Reflection of pectoralis minor

The exposed lesser pectoral muscle has been divided at its insertion and beginning at the very apex of the axilla close to the clavicle where the subclavicular glands are situated the axillary fat and glands have been stripped downwards from the axillary vein which is now exposed

some retraction of the divided arteries is avoided *Should this arise* and if the end of the artery cannot be found the invisible bleeding point must be underrun by a suture introduced deeply into the intercostal space with a small semicircular needle The muscle is lifted from the chest and turned outwards and the external anterior thoracic nerve and the vessels which run with it are divided where they pierce the costo coracoid membrane

The pectoralis minor now comes into view and is best removed except in early cases It is divided at its costal origin

The pectoral muscles are then cut across at their insertion respectively into the humerus and the coracoid process and the whole mass of tissue is allowed to fall over towards the axilla (Fig 334)

Removal of axillary contents.—The costo-coracoid membrane now freely exposed is cautiously divided just below the clavicle and the fat at the extreme apex of the axilla is thus brought into view. It now becomes easy to reach the highest axillary glands—subclavian in the strict sense of the word—which so easily escape notice unless they are carefully looked for. The clearing of the axilla should be begun at the very apex of the space hard by the clavicle. The fat in this situation is swept downwards with gauze, exposing a short length of the vein, internal to which a lymphatic cord, sometimes indurated, will be found running upwards into the posterior triangle. This should be seized with dissecting forceps and broken off as high as possible. Downward sweeps of the gauze now expose one or two small tributaries of the axillary vessels, which are caught and divided. On the inner wall is seen the first digitation of the serratus magnus, which is cleared until the external respiratory nerve of Bell comes into view lying upon it.

The next step is one which may be described as the key to the quick and complete clearing of the axilla, or so at least I have found it. As soon as the nerve of Bell is seen, a closed pair of dissecting forceps is pushed directly backwards through the tissues just external to it and right through the fascia covering the subscapularis muscle, until the red fibres of that muscle are exposed. The point of the forceps is moved outwards, and a piece of gauze introduced into the interval thus made sweeps all the tissues of the axilla outwards. This manœuvre exposes the intercosto-humeral nerve, which is injected with alcohol and then divided. Similar treatment should be meted out to the lateral cutaneous branch of the third intercostal nerve, which lies a space below. The long subscapular nerve, which lay just external to the forceps, is at the same time placed on the stretch, and can be cleared with gauze from above downwards. This exposes the subscapular vessels, several branches of which will require ligation.

The upper half of the axillary vein is now exposed, but the lower half is still covered by a definite fascial layer lying behind the tendon of the great pectoral. This layer is freely divided either on a director or, if practice justifies boldness, by a direct knife-cut in the line of the vein. A small artery is constantly found in this layer of fascia.

The remainder of the serratus magnus is now cleared by bold gauze dissection backwards, or, if the proximity of the growth makes it necessary, a superficial layer of the muscle is removed by the knife. Either process stops just in front of the nerve of Bell, which should be carefully preserved. If the muscular surface has been shaved off, the fibres of the elevated portion are cut across just in front of and parallel with the nerve. The fatty tissue of the lower axilla is thus reached again, and the process of sweeping outwards with gauze is resumed until the edge of the latissimus dorsi comes into view. The surface of this muscle is cleared with a knife as far as is necessary to secure the desired circle of fascia concentric with the primary growth.

This part of the dissection varies much in extent, according to the situation of the growth

If, in the early stage of the operation, the skin flap has been reflected backwards to the full extent desired, the breast will now come away If it is found that the skin flap has not been fully reflected the process may be best completed by replacing the hanging breast in position on the thorax The assistant draws it inwards and places the tissues on the stretch while the operator rapidly and easily completes the reflection of the skin flap and the removal of the breast

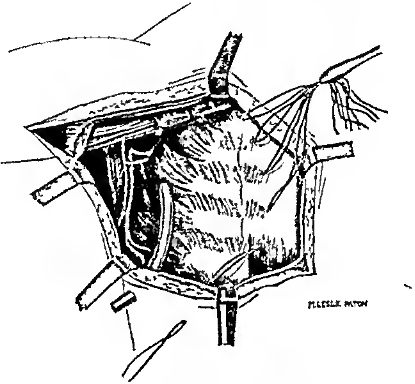

Fig 335 —Insertion of radium tubes

The breast has been removed the radium tubes have been placed in position and the drainage tube has been inserted.

If the operation is performed systematically it will not be found necessary to do any " pecking and minor dissection afterwards in the axillary region Search should be made however, for hard glands along the upper part of the brachial artery

If an adequate supply of artery forceps is available, say two dozen, no vessels have hitherto been tied The ligation of the vessels is the next step, and I have always used very fine silk, 000 Japanese or fine linen thread boiled and then soaked in 1 1000 watery flavine. Catgut has less frictional grip, and for this and other reasons is not so safe

The whole field of operation is now mopped carefully, with a pushing, not a rubbing movement, and the smallest oozing points are ligated,

In order to wash away any loose cancer cells and prevent implantation, the wound is irrigated copiously with 2 to 4 pints of 1-in-2 000 perchloride of mercury at a temperature not exceeding 102° The mercury will presumably coagulate any isolated cancer-cells The wound is now flushed with warm saline to get rid of the mercurial solution which might damage the surface of the radium tubes

Radium tubes or needles are now introduced (Fig 335) A drainage tube about the size of a No 8 catheter is introduced posteriorly through a stab-wound

Search is made that no swab is left behind, and the wound is then closed

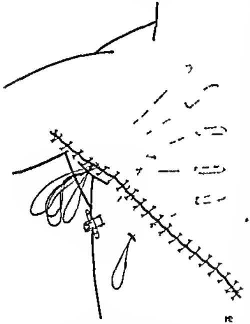

Fig 336 —The incision sutured

The ends of the silk attached to the radium tubes are seen hanging out of the incision. The positions of the buried tubes are indicated by dotted lines

Sutures.—Trial is made how best the incision may be brought together The problem varies in each case according to the situation of the growth in the breast and to the degree of laxity of the skin The most striking indirect advantage of the wide fascial removal now becomes evident This wide removal of the deep fascia so mobilizes and frees the surrounding skin that, even after the removal of a 5 in circle of integument, the edges of the incision can usually be brought together without the use of tension stitches, by a single continuous suture of fine catgut or silk, or by metal clips Tension in the skin flaps—the principal cause of prolonged shock, of pain and discomfort to the patient, of impaired circulation in the skin flaps and of delayed union and ulceration in the sutured incision—is thus generally avoided (Fig 336)

Often it will be found best to bring the edges together in triradiate fashion, in other cases as a sinuous line In growths of the upper and outer quadrant some difficulty may be encountered in covering the raw area and in these cases the axillary flap of skin may be pulled inwards to assist in covering the thoracic gap It is rare to meet with a case in which it is impossible to bring the edges of the incision together but this may happen in thin women with very small breasts and an ill developed thorax—especially if, on account of skin adhesion it has been necessary to remove an unusually large circle of the integument. In all cases where tension of the flaps is threatened, immediate

skin-grafting by the Thiersch method should be done, and is most satisfactory in its results

Alternative method of fashioning the skin-flaps.—After the ring incision has been made, but before the axillary and epigastric incisions have been marked out, the tedious process of dissecting up the skin-flaps may be quickened by the following manœuvre A sharp-pointed narrow knife with a blade 3 in long is pushed into the mid-plane of the subcutaneous fat from some convenient point in the ring incision in a direction radially away from the growth so that the flat of the blade lies parallel with the skin surface The left hand is now placed flat upon the skin surface and the assistant pulls the breast over in the direction towards which the handle of the knife is pointing, so as to render the tissues tense With a sawing movement the knife is now rapidly carried subcutaneously round the whole circumference of the ring incision splitting the subcutaneous fat into two layers over an annular area 3 in in width on all sides of the skin incision The axillary and epigastric skin incisions are then made, and the operation is completed in the usual manner Great care is necessary to prevent the point of the knife from coming too near the skin surface and thus scoring the skin flap and imperilling its nutrition and in spite of the saving of time which it secures, I hesitate to recommend "*subcutaneous transfixion* as a routine method for forming the skin flaps though, except in thin subjects I always use it myself It should be used when there is a fairly thick layer of subcutaneous fat and when the operator is confident that he can avoid scoring the flaps with the point of the knife (*See* Fig 331)

Alternative method with deferred raising of the posterior skin-flap.—For several years past I have modified the operation just described by making the raising of the posterior skin flap the last step of the operation, instead of one of the first Two advantages are gained (*a*) The risk of chilling the badly nourished posterior flap is avoided since its full blood supply is maintained to the end of the operation (*b*) The removal of the posterior part of the fascial circle is technically much *facilitated*

The general course of the operation is unaltered, except that after raising the anterior skin-flap, delimiting that portion of the fascial circle which forms its base, and raising the edge of deep fascia round the delimited portion of the circle, the removal of the pectorals and the clearing of the axilla is next undertaken When the breast falls outwards the dissection is continued on the inner wall of the axilla, deep to the deep fascia until the edge of the latissimus comes into view, and even further, clearing the surface of that muscle until it is considered that the periphery of the fascial circle has been reached A folded towel is then placed upon the stripped thorax, and the breast is replaced over the towel in its normal position The posterior skin-flap is now dissected up as far as the line to which the deep fascia has been undermined The breast is again allowed to fall outwards It is now

attached to the body only by a sheet of isolated deep fascia and the operation is completed by the division of this sheet of fascia along the base of the posterior skin flap

Alcohol injection of nerves—The operation is often followed by persistent neuralgia down the back of the upper arm in the distribution of the intercosto humeral nerve I find that this sequela can be prevented if, when the intercosto humeral nerve and the lateral cutaneous branch of the third intercostal nerve are exposed in the stripping of the inner wall of the axilla, these nerves—before they are divided—are injected with a few minims of absolute alcohol The procedure only takes a few seconds and is well worth doing

Constitutional effects of the operation.—The operation by scalpel for mammary cancer inevitably produces some degree of immediate shock I have never, however, seen dangerous shock during the operation For its prevention it is, I believe, important to keep the skin-flaps, and the thorax generally, covered with hot towels so far as the operator s convenience will allow The persistence of shock for some days appears to depend almost entirely on chill during the operation and upon tension in the skin flaps and the pain associated therewith At any rate, I have noticed, paradoxical as it may appear, that the shock of the operation just described passes off much more quickly than the shock which follows the less extensive operations described in the earlier textbooks, in which tension sutures are necessary for the approximation of the skin-edges Recovery is rapid, and pain usually ceases within twenty four hours

After-treatment.—If hæmostasis has been carefully attended to, the many-tailed bandage may be applied quite loosely A tight chest bandage is uncomfortable and even dangerous It is also harmful to the nutrition of the flaps

The arm is not included in the chest bandage, but is placed in a separate sling, which is then attached by a safety-pin to the chest-bandage beneath Discomfort is thus avoided while the necessary restriction of movement is secured One injection of morphia or $\frac{1}{12}$ grain of heroin may be necessary on the night of the operation Feeble subjects may be given a mixture containing small doses of digitalis and brandy for a few days If there is any history of or tendency towards bronchitis, the patient should be placed in a semi-sitting posture from the evening of the day of operation A daily injection of transpulmin for three days helps to prevent lung complications The dressing is changed, and the drainage-tube removed or shortened after twenty-four hours The drainage tube should never be retained beyond forty eight hours The patient usually gets up on the fifth day, or as soon afterwards as she experiences a desire to do so Rough nursing or voluntary movements of the arm before the wound is healed are apt to be followed by the collection of serum beneath the flaps, or by gaping of the edges of the wound A serous

collection is also likely to form beneath the flaps in the epigastric region if the bandages are allowed to become too loose Stitches should not be removed too early and when they are taken out if there seems any risk of gaping a series of collodion strips should be placed across the wound Gentle nursing and minimal movement are essential to the smooth convalescence of these cases The patient is usually able to leave the hospital or nursing home in fourteen to twenty one days After the end of the third week systematic measures must be taken to mobilize the scar upon the chest Massage in the ordinary sense should be avoided Passive and active movements of the shoulder joint and rocking the skin upon the ribs will do all that is necessary for the recovery of full movement

I invariably recommend a short course of deep X ray treatment as a prophylactic against recurrence after the operation It is I think doubtful whether an extended course is advisable but after an interval of from three to six months the course may be repeated

Difficulties of the operation—*Hæmorrhage* may be trouble some especially in the young and full blooded and for this reason the operation should not be done in the immediate pre menstrual period It is important to reduce all bleeding to a minimum in order to prevent shock and collapse Ether as already pointed out is an unsuitable anæsthetic Neither chloroform nor a chloroform ether mixture excites the circulation so much and these are to be preferred A preliminary morphia injection helps to quieten the circulation Res piratory obstruction cyanosis and congestion tend to increase bleeding and must be avoided and this is helped by the administration of oxygen in a minimal stream throughout the anæsthesia At least two dozen artery forceps should be at hand so that bleeding (not oozing) points may be at once seized by the assistant As far as possible vessels should be clamped before they are divided This applies especially to the vessels in the axilla and to the perforating intercostal arteries

Adiposity while it increases the actual amount of cutting really facilitates the operation It renders easier the elevation of the flaps without risk of including in them the dangerous deep fascia and facilitates by providing plenty of slack the subsequent closure of the wound In such subjects a knife larger and stouter than ordinary the so called breast knife may be used with advantage

The operation is troublesome in thin patients with little subcutaneous tissue and with an ill developed thorax In these patients the flaps are necessarily thin ill nourished and apt unless great care be taken to contain patches of deep fascia There is no such reserve of skin as a fat person possesses and skin grafting is more likely to be necessary The flaps unless extra care be taken are more likely to be affected by chill during the operation

Peripheral position of the tumour—The operation is easiest when the growth lies under the nipple and is especially troublesome when the growth is at the axillary margin

Adhesion of infiltrated glands to the vein—This difficulty must be dealt with boldly by exposing the vein above and below the adherent mass clamping it in both situations resecting the vein and the adherent mass and tying off the ends of the vein not forgetting to tighten the first hitch of the knot ***after*** the forceps have been taken off It is very unsafe to ligature the vein first and then to resect it If this is done the ligatures are likely to slip

Resection of the axillary vein is not followed by any serious consequences

Envelopment of the axillary artery by growth—If detected in time this should lead to the abandonment of the operation In one case in which I accidentally wounded an axillary artery, much displaced and surrounded by growth and in which both the artery and the vein were resected neither failure of nutrition nor paralysis followed The artery was much reduced in calibre by the constriction of the growth and probably a good collateral circulation was already present In a second case I deliberately resected the artery and vein without any impairment of the use of the arm

Retraction of a divided perforating intercostal artery—I have already said that these arteries should be seen and clamped before they are divided If cut short or torn across the bleeding vessel may retract between the intercostal muscles The application of forceps is then difficult or impossible and the artery must be secured by under running The ligature threaded in a small semicircular needle is passed deeply into the intercostal space first on one side of the bleeding point and then on the other It is then tied rather tightly I have never found it necessary to expose and tie the internal mammary artery

Avulsion of tributaries of the axillary vein—In old people the veins are very friable and any undue pulling during the axillary dissection may tear away a tributary of the axillary vein leaving a hôle in the main vein The bleeding point should be seized and tied in the usual way even though considerable narrowing results It is rarely necessary to ligature the axillary vein above and below

Adhesion of glands to nerves—Any nerve in the axilla to which a gland is firmly adherent should be resected with the gland and the *nerve-ends if possible sutured together* Firm adhesion to the brachial plexus or its main branches involves the abandonment of the operation and is only seen when there is diffuse infection of the axilla

Pneumothorax—It is very easy in patients with atrophied intercostal muscles to puncture the pleura with the point of an artery forceps while seizing a divided perforating intercostal artery The accident need not occasion much anxiety If the puncture cannot be closed by a stitch the assistant should press a swab over it until the end of the operation when the flaps are brought together over it On one occasion I punctured the pleura while introducing a radium tube into an intercostal space A considerable amount of air entered and this patient suffered from distressed breathing and some amount of shock for several days

Difficulty in closing the wound —Formerly surgeons experienced great difficulty in closing the wound after the operation for breast cancer Deep tension sutures were inserted and the flaps forcibly approximated In consequence, the patients suffered great pain and shock, persisting for days after the operation The difficulty arose from the restricted scope of the operation then practised Undermining of the flaps was not understood and the adjoining skin was therefore not mobilized

A similar difficulty arises when very large areas of skin are ablated and thus in Halsted s operation no attempt is made to bring the flaps together, and the operation is terminated by immediate skin grafting of the raw area

I have shown that it is sufficient to remove a moderate amount of skin, and that extensive undermining of the flaps is a necessary step to the complete removal of the disease Recognition of these two facts has removed the surgeon s difficulties in closing the wound

Skin-grafting.—Skin grafting should be done by Thiersch s method and at the time of operation The grafts then almost invariably " take ' well They are to be obtained from the front of the patient s thigh Grafting is usually necessary in carcinoma of the male breast In sarcoma of the breast also owing to extensive skin adhesion and the amount of skin that has to be removed it is generally unavoidable

To ensure satisfactory healing after skin grafting it is necessary that the flaps should be induced to adhere to the deeper tissues all round the grafted area in spite of the slide produced by the respiratory movements It is further necessary that the axillary cavity should be completely closed and shut off from the thoracic wound The first object is promoted by snicking the edge of the flap all round by radiating cuts ½ in long at intervals of ½ in , a step which also increases the length of the coast-line from which epithelium may spread over the grafted area if any of the grafts fail The edges of the flaps are then sewn down to the intercostal muscles at intervals by interrupted sutures (Halsted) before the grafts are applied The closure of the axilla is secured, at the point where that cavity is coterminous with the grafted area, by a stitch taking up first the edge of one flap, then the exposed surface of the intercostal muscles then the edge of the other flap This stitch is essential to the proper closure and rapid healing of a grafted wound *If the axilla cannot be* closed, skin grafts must be applied to the whole of its vault, and Halsted recommended this as a routine method In skin grafted cases it is especially important to observe a rule which applies to all radical operations, namely, that during the first few days nursing manipulation should be reduced to a minimum that *two* nurses must assist when the patient is moved, and that the patient should be rolled not sat up in bed The grafted area should not be dressed until the fifth day The grafts should be subsequently exposed to the air, covered only by a wire-gauze cage over which a single layer of gauze is thrown If crusts begin to form on the grafted area periods of hot fomentation should alternate with periods of exposure

The Diathermy Operation for Breast Cancer

General considerations. (*See also* p 577)—The mass of tissue heated by the passage through the body of a surgical diathermy current may be considered as a cone or pyramid with its base formed by the neutral or plate electrode and its apex at the point with which the needle electrode is for the moment in contact The temperature attained by any given section of the cone during the passage of the current is inversely proportional to the area of that particular section As the needle moves the boundaries of the cone alter, but near its base the change in outline is negligible Here, throughout the operation, a heating effect, slight but continuous, affects a large area of tissue If within this area there is a quiescent bacterial focus, such as an old phlebitis, it may be roused into activity, and in one case in my experience a fatal staphylococcic septicæmia resulted Not only therefore must the position of the neutral electrode be carefully chosen to avoid such areas, but the total amount of current put through the body must not be too large, that is to say, the operation must not be too prolonged The neutral electrode is best placed behind the loin The intensity of the current must not be higher than is necessary to secure a cutting effect The flaps when cut should not feel hot through the operator s gloves, and there should be no visible charring on the cut surface Special care should be taken not to pass an undue amount of current through the base of the flap, or the whole flap may slough

It would appear that diathermized tissues possess a rather lowered resistance to infection and in a small proportion of cases, after an apyrexial convalescence, about the tenth day the temperature rises, the skin edges become red, and pus may form beneath the edges of the flaps, and even extend beneath them, as the result of infection by the skin organisms at the suture line Spraying the suture line with staphylococcus antivirus will usually arrest the process in an early stage This liability of the skin flaps to late infection by their own bacterial flora is a serious objection to the diathermy operation Pre operative injection of one or two doses of mixed staphylococcus vaccine would appear to be a wise precaution

The general rule, after a properly performed diathermy operation is apyrexial convalescence and primary union, and this rule is almost invariable in private practice, but in hospital a small proportion of the cases have their convalescence delayed by this late auto-infection of the skin flaps It is of great importance that in the first few days after the operation nothing should be allowed to disturb the incipient adhesion between the deep surface of the skin-flaps and the deeper tissues upon which they lie Skilful and gentle nursing is an absolute essential, and the earlier dressings should be done by the operator himself Movements of the patient in bed should be reduced to the necessary minimum and should be carefully carried out by two nurses so as not to produce a "slide" of the flaps upon the deeper tissues The patient herself must be told to keep quiet in bed and must not be

allowed to use the arm When the dressings are changed they must be carefully peeled back so that the underlying skin-flap to which they often adhere is not lifted up with them For the same reason the patient must be dressed without allowing her to sit up The dressings on the front of the thorax are first changed, and the old dressing is pushed back between the arm and the thorax, then the arm is slowly moved across the front of the chest while the patient's trunk is rotated about twenty degrees towards the sound side The dressings in the axilla and at the back can then be easily changed

It may be here re-emphasized that the education of a surgeon in the technique of surgical diathermy is necessarily a gradual process, that familiarity with the method should be acquired by its use for smaller operations before it is adopted for such an extensive operation as that for carcinoma of the breast Given, however, the necessary technical knowledge and familiarity with the method and a really efficient machine, diathermic excision has the advantage of minimizing shock because it maintains the body-temperature greatly lessens hæmorrhage and probably divides nerves without seriously stimulating them Nevertheless, after a lengthened trial of diathermy, I prefer, as a rule, the scalpel operation

Technique of the operation.—The first steps of the operation are the same as in the scalpel operation A circle of skin four or five inches in diameter with the primary growth at its centre, is marked out by a scalpel scratch for removal The flaps are marked out by two incisions, enclosing this circle which extend from the epigastric angle to the insertion of the pectoralis major The flaps are now undermined for about an inch all round, still with the scalpel in the mid plane of the subcutaneous fat The knife is now exchanged for the diathermy needle, and with it the elevation of the anterior skin-flap is completed so that the anterior half of the circle of the deeper subcutaneous fat, ten to twelve inches in diameter, and with the primary growth at its centre, is marked out for removal The exposure of the posterior half of this same circle is deferred until the last moments of the operation, in order that the nutrition and warmth of the posterior flap may be safeguarded to the utmost This, I think, is an important *modification of my former operation*

All round the exposed semicircle of the subcutaneous fat the needle now is carried down to the level of the deep fascia, and, the flap being carefully retracted, the edge of the deep fascia is raised exactly as if the scalpel were being used While the axillary dissection is being performed, the needle is laid aside and the dissection is done with gauze and dissecting forceps in the manner already described The operation is then continued with the diathermy needle on exactly the same lines as if a knife were being used The final step of the operation —the raising of the already undermined posterior flap—is done with the scalpel to avoid passing an undesirable amount of current through the base of the flap

Prophylactic use of radium tubes or needles during the operation.—For the past seventeen years I have made it a routine practice to introduce radium tubes at the end of the operation in those situations beyond the range of the operation where experience has shown that recurrence is most likely to take place. More than half the recurrences seen after the modern operation, at any rate in my experience, originate in the lymphatic glands *indirectly* connected with the breast, namely, in the anterior mediastinal and the supraclavicular glands. The enlargement of a gland overlying the subclavian artery at the lower and inner angle of the posterior triangle, or the appearance of nodules at the inner end of the first, second, or third costal interspaces on the same side as the original growth is the first overt sign of an infection of these glands which must have been present microscopically at the time of the original operation.

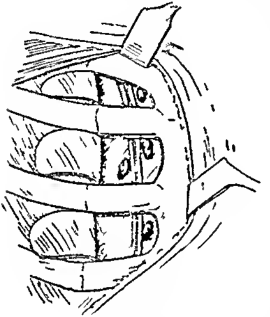

Fig. 337.—Handley's operation for the removal of anterior mediastinal glands.

(*Handley's "Cancer of the Breast"*)

The breast has already been removed, and the intercostals are exposed. Above are seen the remaining clavicular fibres of the great pectoral muscle. The skin flap is being retracted. At the inner end of the first, second, and third intercostal spaces small flaps consisting of the anterior intercostal fascia and the internal intercostal muscles have been marked out and raised. The internal mammary vessels, with the anterior mediastinal glands in front of them, have been exposed preparatory to the removal of the glands.

Some operators have advocated the routine removal of the supraclavicular glands as a part of the original operation, but most surgeons will agree that this extension of the operation is an undue tax upon the patient's strength.

It is quite feasible also to remove the gland-bearing tissue in the anterior mediastinum (Fig. 337), and I have done this in five cases. For details of the method employed the reader may consult the second edition of my work, Cancer of the Breast (John Murray). All the cases recovered. In only two cases were infected glands detected in the tissue removed, and both these patients died within a year of internal recurrence. It therefore appears that obvious infection of these glands connotes wide dissemination elsewhere. For this reason, and as an undesirable prolongation of an operation already severe enough, I would deprecate the routine clearing of the anterior mediastinum.

There seems, on the other hand, no valid argument against the

routine employment of buried radium-tubes introduced in close proximity to these dangerous glands as a part of the radical operation Their employment does not appreciably prolong the operation, and I can state with confidence that it does not add to its risk

Details of the method —Radium tubes with a pointed end should be used Stout silk or fishing gut is attached to the tubes, emerging either through the main line of suture or through separate punctures made in the flaps If the pull on the threads during removal is at all oblique, the tube tends to become oblique to its track of introduction and therefore to become wedged This is particularly the case if the eyehole in the cap of the tube is bored some little way from the end of the tube The eyehole should be bored as close as possible to the end

Five tubes of radium each of 2 mg are used One of them should lie above the first rib just superficial to the first part of the subclavian artery This tube may either be introduced through a separate puncture over the supraclavicular triangle or it may be pushed up into place through the axillary wound just internal to and rather above the axillary vein, along the line of the trunk lymphatic vessels

The remaining four tubes lie respectively at the inner end of the first, second, third and fourth intercostal spaces They are pushed boldly into the intercostal muscles until their pointed ends impinge on the border of the sternum or just pass behind its edge The tubes should have a platinum wall 0 6 mm thick to exclude soft α and β rays from the tissues They should be left in place for five days If the overlying skin flap is unusually thin or badly nourished, this period should be reduced If the case is a late one, two extra tubes should be used in the supraclavicular triangle, and one at the inner end of the fifth intercostal space If axillary infection is advanced three longer tubes, each of 3 mg should be placed upon the inner wall of the axilla, suitably spaced in the superficial fibres of the serratus magnus

This procedure has raised the percentage of my cases free from recurrence at the end of three years from 47 to 56 In one case a serious pneumothorax accompanied by shock, occurred from the puncture of the pleura by a radium tube but in no other case has their use introduced any element of anxiety In thin patients a patch of superficial radio-dermatitis, perhaps the size of a shilling, may occur over each of the tubes, appearing as an erythema of some weeks' duration, which subsides, leaving a pigmented patch

Plastic methods of operation on breast cancer.—The object of the surgeon in operating upon breast cancer is the complete removal of all those tissues which are likely to harbour extensions of the disease and of those tissues only This object is so difficult of attainment that, if subsidiary aims are admitted to competition with it, failure in the main objective is a likely result For this reason all plastic methods which divert attention from the ablation of the growth to the repair of the wound are radically unsound and dangerous Tansini practises a very free ablation of the growth with what appears to be an

unnecessarily extensive removal of the surrounding skin but without undermining the skin flaps He then fashions a flap in the scapular region The anterior edge of the flap is formed by the posterior edge of the area of skin removed with the growth Its posterior edge is near the inner border of the scapula its pedicle is above and its long axis is directed downwards towards the lower angle of the scapula This flap is rotated forwards beneath the arm until it covers the denuded area in the front of the chest and is there fixed by sutures The gap over the scapula is closed by the approximation of its anterior and posterior edges with sutures leaving a linear wound

In this method an unnecessary amount of skin is sacrificed while on the other hand the extent of deep fascia removed is restricted in the posterior axillary region by the necessity of conserving the blood supply of the scapular flap In the base of this flap it is very probable that a segment of the growing edge of the disease will be left intact to cause recurrence

Danger of inelastic methods of operation—All methods which prescribe a fixed mode of attack without regard to the situation of the growth in the breast are essentially irrational A carcinoma of the outer edge of the breast requires different treatment from one of the inner edge The various faults apparent in different methods of operation mainly spring from a failure to base the operation upon a true and coherent conception of the mode of spread of the disease The facts of dissemination are now well known and there is no excuse for failure to take them into account

Common faults in operations for breast cancer—These may thus be summarized —

(a) The pursuit of minor aims which distract attention from the one great object of eradicating the growth
(b) Failure to base the operation rigidly upon the known facts of dissemination In detail this is seen as —
(c) Removal of an unnecessarily large area of skin
(d) Removal of an inadequate area of deep fascia
(e) Failure to centre the operation upon the primary growth owing to the adoption of some rigid method which does not adapt itself to the varying situations of the growth in the breast
(f) Failure to reach the apex of the axilla and to remove the subclavicular glands there situated

Other faults now rarely seen in British surgery are —

(g) Obviously inadequate operations e g resection limited to the removal of the portion of breast containing the growth
(h) Failure to remove the pectoral muscles

Difficulties in the after treatment—*Shock* must be treated on general principles Usually it is only seen after excessive bleeding and especially when ether has been used as the anæsthetic If the

hæmostasis has been careful and complete, saline and stimulants can be given immediately after the operation without fear of exciting further bleeding. Severe and persistent shock was formerly common after the operation, owing to pain arising from the extreme tension of the sutures co-apting the flaps. Tension of the flaps must be avoided, if necessary, by skin-grafting. A third cause of shock is chill from neglect to cherish the flaps with hot towels during operation.

Collection of serum under the flaps is the commonest minor complication. It is often due to rough nursing or restlessness. It appears to result from the section of the lymph-vessels, especially in the axillary region, which is inevitable during the operation. The flaps are separated from the chest-wall by a fluctuating water-cushion of serum. The difficulty must be met by daily insinuating a director at some point along the line of sutures and squeezing out the fluid. It is not advisable to re-introduce a drainage-tube, for fear of sepsis. If serum continues to collect after the incision has healed, a few days' hot fomentation will often cause the flaps to adhere to the chest-wall and will stop the lymphorrhœa, or the flaps may be fixed down by strips of strapping across the chest Purgation with mist. alba may help. The arm should be kept in a sling until the lymphorrhœa has ceased.

Lymphorrhœa does not imply a bad ultimate prognosis. One of the most persistent cases I have met with remained free from recurrence seventeen years after the operation, when she died of an intercurrent disease.

Sloughing of the flaps is rare, except from unnecessary chill during operation, from undue tension, or from scoring of the flaps near their bases. The slough should be cut away with scissors, and the exposed area skin-grafted as soon as the flaps are adherent to the intercostals.

Ulceration of the edges of the flaps is a common but not a serious trouble. Should it occur, the skin-edges should be sprayed twice daily with staphylococcus antivirus, the stitches should be retained longer than usual, and fomentations applied to clean up the wound.

Oxygen for the flaps.—In certain cases, especially if the patient is very thin or the growth excentric in the breast, anæmic areas may be seen at the end of the operation towards the edge of one of the flaps. In such cases it is my custom to place beneath the dressing the end of a small rubber catheter with its orifice in contact with the anæmic area. Through this catheter, during, say, the first week, a continuous current of oxygen is played upon the skin surface. The oxygen passes through a Wolff's bottle in which there is some water, and should be regulated to about 20 to 30 bubbles per minute.

Retraction of the flaps owing to yielding of the stitches, to their premature removal, to rough nursing or to restlessness, may delay convalescence very considerably. It is more likely if a heavy opposite breast is allowed to drag on the wound. This may be prevented by tilting the patient over to the side of the operation, or by applying on the outer side of the opposite breast a broad strip of strapping, which is carried over the wound and attached to a weight of 2 or 3 lb. hanging

over the side of the bed The sutures must not be removed too early, and if not causing irritation they should be left for nearly a fortnight

Suppuration of the wound is a rare and serious complication It is rarely fatal, but may lead to empyema It must be treated vigorously by re introducing large drainage tubes at all dependent points and by frequent irrigations with 1-in 1,000 flavine Carrel s method may be used with advantage

Syncope—In one case, unique in my experience, the patient died of sudden heart failure within a few hours of the completion of the operation

Infections during convalescence—In a general hospital ward, infection from other cases can never be entirely excluded I have seen fatal influenza and broncho pneumonia, and two serious cases of erysipelas, both beginning in the second week of a normal convalescence

Limitation of freedom of movement of the arm—Some surgeons, in order to maintain free abduction, keep the arm abducted nearly to a right angle throughout convalescence, and the practice is no doubt successful in its object It is, however, unnecessary, and there is a serious objection to it in that it increases the tension on the skin flaps It must tend, therefore, to restrict their already precarious blood supply, and to favour sloughing and ulceration of their edges

In my own practice the arm is kept fixed to the side in a sling until after the stitches are removed, to ensure relaxation of the flaps and absence of movement between the apposed skin-edges When the union is firm at the end of a fortnight or three weeks, abduction is first allowed then encouraged, and then insisted upon systematically If necessary abduction exercises, such as "climbing" the hand up the wall are given If the skin is tacked down to the ribs, massage, not of the skin, but of the skin upon the ribs, will soon loosen the adhesion The hand is fixed upon the skin, which is then rocked in various directions upon the underlying ribs If these simple precautions are taken there is no fear of limitation of movement

As Kocher points out, leaving the pectoral is more likely to lead to limitation of movement than is total removal Any remaining portion of the muscle, if deprived of its nerve supply, will become contracted and fibrotic

If the arm is kept to the side for several months, owing to nervous dread of movement, abduction is likely to be limited by the formation of a cicatricial bridle in the line of the scar, especially if the scar follows the anterior margin of the axilla Such a bridle may require subsequent excision

RECURRENCE

It would be possible to maintain that modern methods of operating for breast cancer have almost abolished recurrence for, strictly speaking recurrence means a return of the disease in the field of operation and this after the modern operation is a rare event It is however, customary to include under the term recurrence any clinical manifestation of the disease which appears after the operation as the result

of the development of inappreciable microscopic foci already present at the time of the operation in regions where the knife does not intrude.

Todd and Dawson* give an instructive table showing the sites of the first and second recurrences in 107 cases of breast cancer treated by operation only and not subjected to radiation.

Site	First Recurrence No. of Cases	Second Recurrence No. of Cases
Skin in or near scar	31	2
Deeper tissues of chest wall and axilla	25	3
Supraclavicular lymph nodes	26	5
Peritoneum	3	1
Liver	3	6
Lung	6	22
Other breast	2	4
Other axilla	0	3
Brain	1	1
Spine	8	10
Pelvis	0	5
Femur	2	6
Other bones	0	4
Total	107	72

As the authors remark, the large number of skin recurrences could probably have been reduced almost to vanishing point by adequate post-operative radiation. Since axillary recurrence after efficient operation is a rarity, it is probable that most of the recurrences, 51 in number, under the second and third groups of the table were traceable to infected internal mammary glands. In my opinion this danger can be dealt with much more efficiently by radium tubes implanted at the time than by post-operative radiation.

I have arrived at the following classification of recurrences after operations for breast cancer:—

1. Rapid recurrences, within a year or so of operation. The site of these is variable and undefined. They are sometimes local, but are often internal. In these cases the disease is really inoperable when first seen, and, as a rule, further operation is not possible except in cases where enlarged supraclavicular glands show themselves within a few months of the operation without any other manifestation of the disease.

2. Late recurrences taking place generally more than two years after operation. A large majority of such cases fall into four subdivisions:—

(a) Intercostal recurrence. (c) Spinal and bone recurrences.
(b) Supraclavicular recurrence. (d) Pleural recurrences.

* "Cancer," 1937, Edinburgh.

It is in dealing with late recurrences that the outlook has lately become much more hopeful The prevention of intercostal recurrence has already been considered It is not amenable to operation but we possess resources which in certain cases may keep it in check for years As to supraclavicular recurrence I am certain that in the past such cases have been looked upon from an unduly pessimistic standpoint A carefully planned operation for clearing the posterior triangle is the right treatment and in a proportion of cases may give durable success

Intercostal recurrence —In a regrettable proportion of cases two to three years after the primary operation a nodule or nodules not at

Fig 338 —Typical intercostal recurrence in first and second spaces No other recurrence

first adherent to the skin appears at the inner end of one or more of the first second and third intercostal spaces Later these nodules become adherent to the skin The sternum is also liable to attack by them and a large sternal swelling may then arise Nodules may later present at the inner ends of the lower spaces down as far as the sixth (Fig 338)

Operative treatment and surface radiation are useless in dealing with this form of recurrence but it is not quite so hopeless as it appears Halsted records a success by treatment with the actual cautery I have a case still well twenty years after the recurrence which was treated by secondary X rays In this method X radiation is preceded by local injections of bismuth When irradiated the bismuth particles become a source of soft secondary X rays within the tissues

The preceding methods have been superseded by the use of buried radium A 2 or 3 mg tube of radium is introduced for five to ten days at the inner end of each of the affected spaces deep in the intercostal tissues and well away from the skin Other tubes may be introduced behind or in the substance of the sternum if that bone is

affected I lately showed at the Royal Society of Medicine a patient free from any sign of disease twelve years after treatment of a large sternal recurrence

Supraclavicular recurrence —The first sign of supraclavicular recurrence is the appearance of a large hard gland deep in the angle between the clavicle and the sterno mastoid muscle overlying the subclavian artery Later, other glands appear in the triangle below the posterior belly of the omo hyoid muscle

If the glands are still mobile, operation should be undertaken Even if the gland at the lower and inner angle is fixed, it is sometimes worth attempting to enucleate it, and if a tube of radium is then left for twenty-four hours in the bed from which it came, and if at the same time all the glands in the posterior triangle are excised, a long period of freedom from recurrence may be secured It is, however, useless merely to excise the enlarged glands The adjoining glands, though still normal in size, are microscopically infected Accordingly it is necessary, as Butlin first advised to excise all the glands in the posterior triangle, including the deep cervical glands lying within the carotid sheath At the very least, the gland excision should be carried as high as the spinal accessory nerve

Mode of operation —An incision is made along the posterior border of the sterno-mastoid from the mastoid process to the sterno-clavicular joint Here it turns sharply and follows the clavicle as far as the edge of the trapezius The triangular flap thus defined is raised outwards as far as the margin of the trapezius, and is wrapped in a hot towel Included in the flap are the platysma and a layer of subcutaneous fat A length of the external jugular vein is included, so that this vein is divided twice, once in the upper part of the skin incision, and again where it penetrates the deep fascia just above the clavicle

The posterior border of the sterno mastoid is now defined, and the spinal accessory nerve is exposed at its exit from the muscle and cleared in its course across the triangle Unless this is done, the nerve, which is here embedded in very dense tissue, will certainly be cut during the operation

The sterno-mastoid is now retracted inwards, exposing the anterior belly of the omo-hyoid and the sheath of deep fascia covering the internal jugular vein The fascia is carefully snicked so as to expose the vein, a director is then introduced through the opening in the fascia, first in an upward and then in a downward direction, and the layer of fascia is divided cleanly, along with the omo-hyoid muscle, from the mastoid to the clavicle The clean performance of this step is the key to the whole operation

The jugular glands are now swept outwards by gauze dissection The deep fascia is divided on a director just above the clavicle, and the lower and inner angle of the triangle is opened up Here a large gland, often adherent, is found behind the inner end of the clavicle This part of the dissection is very important When it is accomplished, the gland-bearing layer of fibro fatty tissue can be swept outwards by gauze

dissection with occasional division of small arteries as far as the outer edge of the trapezius The fascia covering the brachial plexus is now exposed, but should not be opened The sheet of tissues is turned back into position, the edge of the trapezius is defined, and with scissors the freed tissues are divided along the outer edge of the triangle The omo-hyoid is cut again near its origin from the scapula and here free bleeding is encountered

A 3 mg tube of radium is then placed with its point deeply behind the inner end of the clavicle, another upwards along the main deep cervical chain, almost up to the base of the skull, one outside the lower exposed portion of the internal jugular vein, one behind and parallel with the clavicle, and one in the outer angle of the posterior triangle The tubes are removed in five or six days No tube should be placed in contact with the brachial plexus The threads emerge in suitable positions along the line of incision For purposes of drainage, and for the withdrawal of the radium tube, a stab wound is made through the base of the flap near the edge of the trapezius The wound is then sutured with interrupted horsehair or by clips

Dangers of the operation —The operation just described is a delicate dissection requiring precise anatomical knowledge, and its dangers are obvious A risk special to the left side is that of wounding the thoracic duct a misfortune which has once happened to me If the accident is detected the injured duct should be ligatured As a rule, the collection of serum under the flap, and copious soakage through the dressings, are the first indication Persistent firm bandaging, preferably by rubber bandages, continued for several weeks, will ultimately staunch the flow in most cases, and a fatal result appears to be rare

If cancer-cells have already passed outside the glands by infiltration of the capsule, an event usually indicated by fixation, operation is likely to be followed rapidly by diffuse cancerous induration beneath the operation flap from implantation of cancer-cells upon the raw surface of the wound The condition of the patient is then much worse than before the operation This danger can be minimized by refusing to operate when the glands are fixed, by burying a whole group of radium tubes in the wound at the time of the operation and by post operative X *radiation* *The two latter precautions may* with advantage be used in all operations for cancerous glands

Not infrequently a moderate lymphorrhœa follows the operation and produces after healing of the wound, a hard lymphatic œdema of the tissues of the operation area which may be mistaken for cancerous infiltration Time brings about softening of the indurated tissue

Other forms of recurrence —Axillary recurrence and recurrence in the subclavicular glands are nearly always preventable Should they occur, they should be treated by buried radium followed and supplemented by X radiation

CARCINOMA OF THE MALE BREAST

About 1 per cent of cases of carcinoma of the breast occur in males

In the male the disease develops under unfavourable conditions as regards the vascular supply of the part and the primary growth often remains small and apparently insignificant Frequently no notice is taken of the growth until it ulcerates that is to say, male carcinoma reaches the surgeon at a later stage than carcinoma in the female

It must not be forgotten that in the male the process of permeation has but a very short distance to travel before it reaches the fascial lymphatic plexus subjacent to the breast There is no warrant for the assumption that when it reaches this plexus permeation spreads in it more slowly than in the female However small the primary growth it is necessary especially if there be ulceration to reckon with the probability of widespread permeation of the fascial plexus

Many surgeons when operating for male carcinoma ignore these considerations and perform an operation they would admit to be hopelessly inadequate in a female

The operation in the male should be conducted on the same lines as in the female The removal of a 4 in circle of skin and a 10 in circle of deep fascia is demanded and the pectorals must be ablated Owing to the absence of fat the raising of the skin flap is a more difficult and delicate operation than in the female and it is very important not to allow the thin flaps to become chilled It is usually impossible owing to the absence of slack to bring the flaps together and skin grafting can rarely be dispensed with

Sarcoma of the Breast

Sarcoma of the breast should be treated on the same lines as carcinoma and removal of the axillary glands should not be omitted Frequently owing to extensive skin adhesion wide removal of the skin is necessary and skin grafting has to be performed

Ultimate Results of the Operation for Breast Cancer

Personal results—It has been my practice not to refuse operation for breast cancer in any case where a favourable result appeared at all possible and while my statistical results have doubtless suffered in consequence some individual patients who on ordinary standards were inoperable have reaped great benefit I may instance a schoolmistress who at the time of the first operation had enlarged glands above the clavicle and in the opposite axilla This patient followed her profession subsequently for five years ultimately dying of thoracic deposits Another patient a washerwoman showed a large secondary deposit in the opposite breast with hard glands in the opposite axilla She followed her laborious work for two years subsequently and then developed signs of thoracic invasion from which she died Other cases had already reached the stage of ulceration when operated upon

Including all the advanced cases in which operation was done more as a palliative than with the hope of cure 47 per cent of those of my patients who could be traced have remained free from recurrence for a period of three years or upwards Since I began to use radium at the time of the operation this figure has gone up to 56 per cent

When it is remembered how few really early cases of breast cancer a

surgeon sees in this country the results are not entirely unsatisfactory I estimate that of the cases of breast cancer which I see 90 per cent already have enlarged axillary glands Local recurrence in or beneath the operation flaps—formerly so common—is now rare and the bulk of the recurrences must be ascribed to carcinoma-cells which already at the time of the first operation had passed into regions beyond the scope of the operation

Results of other surgeons —Sir Watson Cheyne s results published in 1904 showed 50 to 55 per cent of operable cases free from recurrence at the end of three years Halsted in 1907 published a series of 237 operable cases in which 38 8 per cent had remained well at the end of three years 18 cases which could not be traced were considered as dead of their disease Since in my experience such patients may turn up in good health years afterwards Halsted s statistics are probably more favourable than they appear

We are indebted to this surgeon for a careful comparative study of the chances of cases with and without axillary involvement Of the cases where the axilla had not been invaded 80 per cent remained free from recurrence for three years The corresponding figure for the cases *with* axillary involvement was 22 4 per cent only These figures emphasize the importance of educating the public to seek earlier advice

Judd and Sistrunk (Mayo Clinic) reported that of 510 traced cases operated on in 1902–12 44 7 per cent remained well *for three years* and 29 8 per cent for five years

Deaver McFarland and Herman report 84 per cent well after three years in a series of 506 cases of which they were able to trace 150 while 26 per cent were well after five years

Carter Braine and Grant Massie (*Guy s Hosp Rep* 1926 lxxvi 184) give the following statistics —

PERCENTAGES OF THREE AND FIVE YEAR SURVIVALS

AUTHOR	DATE OF PAPER	NO OF CASES	SURVIVAL AFTER 3 YRS	SURVIVAL AFTER 5 YRS
			per cent	per cent
Handley	1922	—	47 0	—
Peck and White	1922	118	—	39 1
Primrose	1923	49	—	44 4
Leeds Series	1926	357	46 7	35 7
Guy s Hospital Series	1926	338	54 1	28 4

COMPARATIVE PROGNOSIS WITH AND WITHOUT GLANDULAR INVASION

AUTHOR	CASES	GLANDS INVADED		GLANDS FREE	
		ALIVE AT 3 YEARS	ALIVE AT 5 YEARS	ALIVE AT 3 YEARS	ALIVE AT 5 YEARS
		per cent	per cent	per cent	per cent
Dahl (1925)	88	20 94	15 79	70 83	66 67
Sistrunk (1921)	218	—	18 90	—	63 00
Guy s Hospital Series (1926)	120	45 80	18 80	86 50	46 00

The most interesting recent operative statistics are those of Gordon Taylor based upon a personal experience of 603 cases at the Middlesex Hospital Only seven cases were untraced Post-operative radio therapy was not used in Group I and Group II cases Radiation alone without operation was employed in 39 instances 3 in Group I 8 in Group II and 28 in Group III In the last group three patients survive 2 now dead lived 8 and 5½ years Among 29 patients judged unfit for radical operation who were treated by local removal of the breast and subsequent radiation 2 only survived in 1938 but the series included survivals of 10 8½ 6 and 5 years The results of Gordon Taylor s radical operations from 1908 to 1928 —603 in number excluding 7 untraced ones—are shown in the following table and the series includes a large number of ten year survivals

CASES TREATED BY RADICAL OPERATION 1908 1928 FOLLOWED UP AFTER 10 YEARS (GORDON TAYLOR) 353

		SURVIVING 10 YEARS	per cent
Group I cases	113	95	84
II	204	60	29 4
III	46	3	6 5

CASES TREATED BY RADICAL OPERATION 1908 1933 AND FOLLOWED UP AFTER FIVE YEARS 497

		SURVIVING 5 YEARS	per cent
Group I cases	163	140	85
II	283	113	39 9
III	51	5	9 8

CASES TREATED BY RADICAL OPERATION 1908 1935 AND FOLLOWED UP AFTER THREE YEARS 551

		SURVIVING 3 YEARS	per cent
Group I cases	172	147	85 4
II	320	150	46 8
III	59	6	10 1

Of 158 patients who survived radical mastectomy 10 years or more 8 survived 25 years 6 between 20 and 25 years 33 between 15 and 20 years and 111 attained a ten year survival *

* G Gordon Taylor *Brit Med Journ* 1938 ii 1069

It is unnecessary to pursue this subject further for owing to differences in the material of different operators to variations in their selection of cases and their method of operation and to the advent of postoperative radiation treatment no close comparison between the different sets of figures can be established It is however interesting to note as measuring the improvement in results to date that v Winiwarter s statistics for 1867 75 showed only 4 7 per cent of cases well for three years and that prior to Halsted s 1889 94 figures showing 45 per cent of 76 cases well for three years the best series of cases could only claim 28 5 per cent of three-year successes In 1889 in the collected German statistics it was found that only 17 2 per cent of patients with breast cancer remained well for three years after the operation Gross writing in 1888 reported that in the United States only 11 83 per cent of cases remained well for three years or over

Immediate mortality —Billroth in 1867–75 experienced a mortality rate of 23 1 per cent in his operations for breast cancer With the advent of Listerism the rate rapidly fell and between 1889 and 1894 Halsted s mortality in 76 cases was nil In 1907 Halsted recorded 232 cases with a mortality of 2 5 per cent Deaver (1898 1918) records 506 cases with a mortality of 0 98 per cent 2 of his cases died of endocarditis and 1 each of uræmia pneumonia and sepsis His estimate of 1 per cent as the present death rate of the operation may be accepted as a fair one Judd in 1912 recorded a series of 609 cases with 8 deaths (pulmonary embolism sepsis diabetic coma)

My experience shows a definite difference between the danger of the operation in a public surgical ward and in a private hospital or house In a ward where clean and septic cases are nursed together the danger of infection cannot be entirely eliminated In my hospital practice up to nine years ago 2 deaths from erysipelas have occurred and 1 from epidemic influenza A fourth death took place from broncho pneumonia These deaths represent a mortality of less than 1 per cent

In my private practice only 2 deaths have occurred one from sudden syncope a few hours after an operation which appeared to have been well borne and one from staphylococcic septicæmia after diathermy The neutral pad had been placed upon the thigh and had aroused an old septic phlebitis in that region

Schwarzkopf s statistics for 1904 11 show a mortality for private cases of 3 8 per cent and for hospital cases of 5 5 per cent and provide confirmation of the statement that the conditions of isolation obtaining in nursing homes and private houses increase the safety of the operation

NON-MALIGNANT MAMMARY AFFECTIONS

Simple Removal of the Breast Mastectomy

The operation for removal of the breast is usually referred to as amputation of the breast The use of the term amputation is however an encouragement to rough and inartistic surgery and should be abandoned in connection with the breast The word mastectomy is more suitable

Indications —Removal of the breast may be necessary for duct papilloma for chronic mastitis occurring towards middle age for tuberculosis or actinomycosis for cases where after an abscess the

remains of the breast are riddled with discharging sinuses and for severe degrees of simple hypertrophy It may also be required for large innocent tumours to which the breast itself forms a mere appendage In tropical countries elephantiasis of the breast may possibly call for it (See also section on Plastic Surgery Vol II)

Incision —An elliptical incision is used removing a comparatively small ellipse of skin But if too small an ellipse is taken the dissection is more extensive and troublesome and the ultimate result less sightly

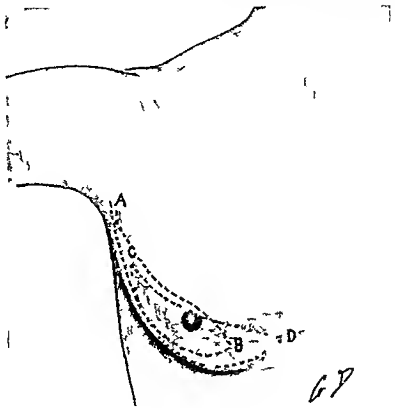

Fig 339 —Simple mastectomy showing alternative skin incisions each removing a narrow ellipse of skin wider in the case of a voluminous breast. The upper limb of the ellipse in any case passes just above the areola

c n is on the whole the best incision a b may be used where an inconspicuous scar is especially desired.

owing to bagging of the redundant skin The stouter the patient and the larger the breast the wider should the ellipse be made Some operators have preserved the nipple operating entirely below its level and cutting across the ducts where they enter it This procedure owing to inevitable fibrous contraction is of no cosmetic value and it certainly introduces a risk of wound sepsis from bacteria contained in the ampullae of the ducts This complication occurred in a case in which I tried the method

Cosmetic considerations are not out of place in the operations, however The lower the incision is placed, the less will it interfere with evening decolletage, and the less obvious will it be to the patient Its upper limb should therefore pass only just above the nipple, while its lower limb passes below the nipple at a distance of 2 to 4 in Such an incision includes the skin which is thinnest, most closely adherent to the breast, and most difficult to dissect up

In ordinary cases the nipple may be taken as the midpoint of the long axis of the ellipse If, however, an inconspicuous scar be especially desired, the incision may be carried only just internal to the nipple, and in compensation extended a little way into the vault of the axilla This incision, it must be recognized, makes the dissection more troublesome in the region of the lower and inner quadrant, and is likely to leave a little redundant skin-fold in this situation (Fig 339)

When the skin has been cut through vertically to its surface all round the ellipse, the knife held at an angle of 135° to the surface, and entering just at the deep aspect of the dermis is once more carried round the line of incision dividing the fibrous septa that pass into the subcutaneous fat from the deep aspect of the skin This allows the skin to retract, and facilitates the subsequent elevation of the skin flaps

Elevation of the skin-flaps.—The next step is the elevation of the skin flaps Here it must be remembered that breast tissue lies very closely underneath the skin The flaps must therefore be cut as thin as is consistent with the maintenance of their nutrition In thin subjects $\frac{1}{10}$ in of subcutaneous fat should be left attached to the skin, in stout subjects as much as $\frac{1}{4}$ in may be allowed Scoring the flap must be avoided, especially near its base

Many operators perhaps the majority, only elevate the flaps as far as the visible margin of the breast but they must be dissected back as far as the real limits of the breast It is important to remove not only the prominent part of the breast but also its thin outlying edge Stiles has shown that the breast is a much more extensive organ than it appears to be Breast tissue extends, in a vertical axis through the nipple from the lower border of the second rib to the sixth costal cartilage at the angle where it begins to sweep upwards towards the sternum *The horizontal diameter extends from a little within the edge* of the sternum opposite the fourth rib to the fifth rib opposite the mid-axillary line One oblique diameter extends from the upper border of the third costal cartilage a little outside the sternum, downwards and outwards to the seventh rib a little in front of the mid axillary line, the other oblique diameter passes from the third rib a little beyond the anterior axillary fold downwards and inwards to the sixth costal cartilage midway between its angle and its sternal end

It will be found that very many operations for amputation of the breast fail to take account of these facts Not infrequently, granular areas of mammary tissue are left at the periphery of the field of operation The removal of the breast is a larger operation than is usually

thought, and it demands careful dissection and a knowledge of anatomy. Since it is often performed to avert cancerous change, it is a serious fault to leave peripheral breast lobules. I have seen carcinoma develop in a residual part of the breast after mastectomy for a non-malignant condition.

Method of raising the flaps.—In thin breasts the flaps are best raised by ordinary careful dissection, care being taken to avoid scoring them. In the submammary fold especial care needs to be taken not to button-hole the flaps. In stout subjects the manœuvre of subcutaneous transfixion, already described (p. 628), shortens the operation considerably, and should certainly be used. An artery of a size requiring immediate forcipressure is constantly found high up in the upper flap. The flaps must be kept warm by relays of hot towels, or their edges may later ulcerate.

When the flaps have been dissected up all round as far as the periphery of the breast, the upper flap is drawn up by two retractors, held a little distance apart, and moved to suit the operator's convenience as he circumscribes the upper and inner hemisphere of the breast by an incision down to the muscle through the deep fascia. The breast is now quickly stripped from the pectoral muscle by long sweeps of the knife parallel with the fibres of the muscle. Several perforating branches of the internal mammary require ligature. In order not to leave any of the deep lobules which lie close to the muscle, it is necessary to clean the muscle, taking the pectoral fascia with the breast. When the serratus magnus is reached, gauze-stripping may be usefully substituted for dissection by the knife. Finally, the fascia along the base of the outer flap is cut upwards with the knife, and the breast remains attached by its axillary connections only. As these are divided, the vessels they contain, especially the long thoracic artery, are secured. A most careful search for bleeding points over the whole field now follows. One or two branches of the intercostal arteries appearing through the serratus magnus usually need tying.

Drainage.—A drainage tube should emerge through a puncture in the base of the posterior skin flap. It should be removed after 24 to 48 hours.

Suture.—A continuous suture should not be used, since it tends to shorten and pucker the line of the wound and to make it thicker and more evident. Interrupted double horsehair sutures are the best, as widely spaced as is consistent with accurate coaptation of the skin-edges. Michel clips may be used, but should be interspersed with a few sutures.

Mastectomy with preservation of the nipple.—The method practised by Stiles for this operation is an extension of the Gaillard Thomas method of plastic resection. He recommends a semilunar incision along the submammary groove for an extent corresponding to the lower and outer hemisphere of the breast. The incision reaches above as far as

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the anterior fold of the axilla In large and pendulous breasts it is advisable to remove a crescentic area of skin

A semilunar skin flap, with its convexity formed by the skin incision, is now raised from the lower and outer hemisphere of the breast The nipple is raised up with the flap by division of the ducts of the breast as they approach their termination . The margin of the outer hemisphere is defined by dissection and this hemisphere is raised from the subjacent muscles The isolated outer hemisphere is pulled strongly towards the operator, who then proceeds to undermine the skin covering the inner hemisphere The assistant meantime retracts the skin flap forcibly upwards Reaching the inner margin of the breast, the operator is now able to raise the inner hemisphere from its deep connections and the breast comes away The assistant then everts the flap, and a careful search is made for bleeding-points The perforating branches of the internal mammary must be ligatured The flap is sutured back in position Drainage is advisable

Personally I do not care for this operation Its cosmetic results are not as good as might be expected *for the nipple, deprived of its* support, hangs down as a flat tag, or may swell from lymphatic œdema The redundant skin, too, is apt to fall into unsightly wrinkles It is more difficult to secure hæmostasis in the recesses of the wound, and the divided main ducts communicating with the interior of the wound may give rise to sepsis Possibly this last risk may be overcome by touching their ends with pure phenol On the whole, I consider that the ordinary operation with removal of the nipple is preferable even from the cosmetic point of view

Complications of mastectomy.—The complications are those arising from sepsis, which of course, is hardly ever encountered

Oozing may follow closure, especially in hot weather and in patients of active and irritable temperament For this reason the operation should not be performed during menstruation Two or three days' rest in bed is advisable before operation on an active and tired woman Serious reactionary oozing is more frequent than after the longer operation for malignant disease, no doubt because less blood is lost during the operation itself, so that the circulation recovers before the small vessels are firmly sealed Careful hæmostasis and an ice-bag over the dressing in hot weather may prevent it Should it take place, and should the flaps be raised by palpable bloodclots and be deeply ecchymosed at the time of the first dressing there is only one thing to be done An anæsthetic must be given the wound opened up, the clots washed away with a forcible stream of saline, and the wound resutured after bleeding-points (often at this time absent) have been sought The wound will now heal almost as well and as rapidly as if no bleeding had occurred If nothing is done and the clot is left to organize there will be ugly and possibly painful fibrosis and contraction, and the scar will be thick and unsightly The clot may also become infected and suppurate

Sloughing of the skin edges may be due to scoring of the flaps, to

cutting them too thin, or to allowing them to be chilled during the operation The flaps are necessarily thin, of low vitality, and likely to be attacked by bacteria from their cutaneous ducts An antiseptic dusting-powder (e g aristol or bismuth subgallate) applied after the operation may prevent this Should slight sloughing or ulceration of the edges occur—and this is the worst that need be feared—they should be sprayed with staphylococcus antivirus and the stitches should be left in longer to prevent retraction of the flaps Any sloughs should be clipped away with scissors—not as a rule a painful procedure—and hot fomentations applied for a few days

The patient, after mastectomy may be allowed to get up as soon as she feels inclined, this is generally about the fifth day Stitches may usually be removed in from five to seven days, and the wound then sealed with collodion The earlier the stitches are removed, the less conspicuous will be the scar

Partial Removal of the Breast

Resection of the breast is sometimes practised for any non malignant condition involving a portion only of the breast—except in the case of

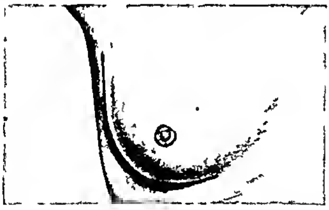


Fig 340 —Gaillard Thomas's operation for removal of simple tumour of breast First stage

The skin incision follows the submammary sulcus.

abscess or an easily enucleable simple tumour A radial incision, over the portion to be removed, may be employed, and through such a simple incision it is possible to remove a large portion of the breast

In performing the resection, care must be taken not to interfere with the duct system of any portion of the breast which is not removed If this rule is violated, obstruction cysts or mastitic indurations may appear in the residual portion of the breast The part of the breast removed should be included between two deliberately-made radial incisions through the breast substance, and these incisions should meet near the nipple, so that a clean wedge of the breast substance is removed Hæmostasis should be very carefully attended to, and it is best to

provide drainage for twenty four hours If the wedge removed is not too extensive the cavity left may be obliterated by the lateral approximation of its walls with buried sutures passed through the breast substance

As an operation resection of the breast is less satisfactory in practice than in theory The condition for which it was performed may later appear in the remaining portion of the breast The operation itself may leave a local induration or an area of skin adhesion which may be

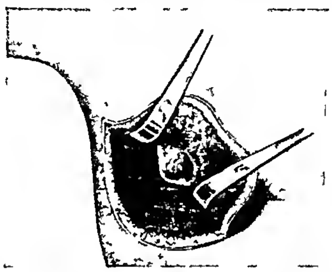


Fig 341 —Gaillard Thomas s method Second stage
Exposure of the tumo from behind. Its capsu e is now to be incised, and the tumour enucleated

a cause of continuing anxiety Therefore in women approaching middle age mastectomy is in most cases preferable to resection

Resection of the breast through a submammary incision—In order to avoid a scar upon the surface of the breast itself Gaillard Thomas of New York in 1882 suggested an incision round the lower hemisphere or the lower and outer quadrant following the submammary sulcus When the upper edge of the incision is drawn up the breast is easily with little dissection turned over so that most of its deep surface is exposed (Figs 340 341 342) Simple tumours may then be enucleated by cutting down upon them through the deep aspect of the breast or a portion of the breast may be resected After this has been done and bleeding stopped the breast is replaced in position and the incision sutured It is usually best to drain

The method of Gaillard Thomas is the method of choice for resection of a portion of the breast in young women if the avoidance of a visible scar is desired and if malignancy can be excluded with certainty If a carcinoma is unexpectedly found the operator will rue his choice of method for it is impossible after such a dislocation of the breast to do a satisfactory radical operation

Healing after the Thomas operation is usually rapid and the cosmetic result good This method is unsuitable for operations on the upper and inner part of the breast

Operations for Mammary Abscess

These abscesses require incision and drainage In order to avoid injuring the ducts the incisions must radiate from the nipple or must

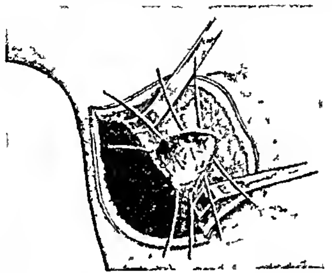


Fig 342 —Gaillard Thomas s operation Third stage

Obliteration of the cavity in the breast left by the removal of the tumour The breast is then allowed to fall back into place and the incision is sutured, with provision for drainage

be made along the circumference of the breast Multiple incisions are sometimes necessary so placed that gravity favours free drainage After the incision is made a finger is introduced into the cavity and all loculi or septa are broken down so that every recess is opened out freely into the main cavity If the original incision proves not to be at the lowest point of the cavity a counter incision must be made at that point and drainage tubes inserted If several independent abscesses are present each must be dealt with in the same way

After treatment —This consists in gradual shortening of the drainage tubes and daily antiseptic irrigation The application of Bier s cupping glasses over the breast often quickly arrests suppuration and replaces it by a serous discharge

Sheild's operation —The abscess is opened in the usual way, and a counter opening is made in the fold beneath the breast just at the margin of the organ The original incision is then sewn up and usually heals by primary union The object is to avoid visible scarring of the breast Sheild further advised the maintenance of elastic pressure upon the cavity during healing by the incorporation of a flat

Turkey sponge in the dressing The arm is fixed to the side and kept in a sling to avoid delay in healing due to action of the pectoral muscle This indeed is the rule in all operations on the breast

Incision through the submammary sulcus—Desmorest has drawn attention to the advantages for the evacuation of pus of a circumferential incision following the line of the lower third or half of the circumference of the breast All collections of pus wherever situated can be evacuated through this incision and the subsequent scar is invisible After the incision is made the breast is turned up so as to expose its posterior aspect through which the abscess or abscesses are opened In most cases of intramammary abscess Sheild s method secures the object aimed at namely an inconspicuous scar in a simpler way An incision in the submammary fold is however the method of choice for *retromammary abscess* In evacuating this form of abscess search must be made for an intramammary prolongation of the abscess cavity and if found such a loculus must be freely opened up into the main cavity Search must also be made for a communication with the thorax in case the abscess has originated in a carious rib or a localized empyema

Enucleation of Fibro-adenomata

The skin incision may be (*a*) a radial incision directly over each of the tumours or (*b*) the Gaillard Thomas incision at the lower margin of the breast (p 645) The tumour is enucleated through an incision on the deep aspect of the breast

Usually the former or direct method is preferable as being easier and simpler The only advantage of the Thomas method is that it leaves no scar on the surface of the breast It is a larger and sometimes not an easy operation

Direct method—The tumour is grasped firmly by the fingers of the left hand and a vigorous cut radiating from the nipple is made over it The cut must freely divide the capsule of the tumour exposing its substance This is the key to easy performance of the operation The capsule is usually feebly adherent to the tumour but firmly adherent to the surrounding breast substance The common mistake is to attempt the difficult task of enucleating the tumour in its capsule from the surrounding mammary tissue before dividing the capsule

When the capsule is divided a blunt instrument is introduced within it and swept round The finger sometimes proves the most effective enucleator

The only common complication is the formation of a hæmatoma in the cavity This is prevented by (*a*) careful hæmostasis (*b*) obliteration of the cavity by one or more buried sutures approximating its sides (*c*) drainage for twenty four hours by a small tube (*d*) firm bandaging (*e*) fixation of the arm to the side

Should a hæmatoma form it will probably be best to open up the wound wash out the clot obliterate the cavity and resuture

Large, soft rapidly-growing adenomata are often best treated by removal of the whole breast

It must not be forgotten that certain carcinomata of low virulence may acquire a fairly complete capsule and may be enucleable without very much difficulty Accordingly, *all* tumours enucleated from the breast must be microscopically examined to exclude malignancy

SURGERY OF DUCT PAPILLOMA AND PRECANCER

In duct papilloma of the breast as evidenced by persistent serous or sanious discharge from one or more of the nipple orifices a simple mastectomy is usually the best treatment if the patient has reached the cancer age This rule however is not without exceptions If physical pride is an important factor it may be recalled that even in fully developed carcinoma treatment by buried radium tubes after the manner of Keynes is frequently successful Surface papillomata are well known to be often amenable to radium why not those within the ducts of the breast ?

Localization of the papillomata.—It is important as a preliminary, if possible to locate the papillomata The number of discharging orifices seen on the nipple is a guide to the number of lobes affected Lenthal Cheatle has demonstrated, by the method of giant sections, that the disease affects the breast by lobes The affected lobes are often outlined as vaguely indurated "mastitic" areas More precise indications can often be obtained by local pressure with one finger upon successive areas of the circle of tissue immediately around the nipple, or further out at the margin of the areola When the diseased lobes are pressed upon fluid is seen to emerge from the nipple The actual papillomata themselves can rarely be felt

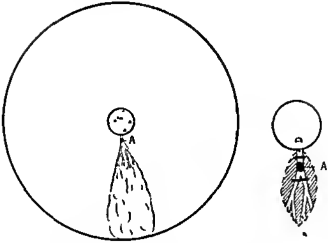
Radium treatment.—Through multiple punctures in the skin surface radium tubes each of 2 or 3 mg and distributed as uniformly as possible, are introduced behind or in the breast, in any case not immediately under the skin, for a period of five to seven days If the papillomata cannot be located, the whole breast must be treated, and it should receive about the same dose as would be given for a carcinoma though the axilla need not be treated Fifty or sixty milligrams of radium will be needed The amount varies with the volume of the breast, and the method is hardly applicable to a very voluminous mamma

If the papillomata have been located, treatment may be confined to the affected lobe or lobes and a smaller amount of radium will suffice

In my experience radium treatment will cure about two out of three cases of duct papilloma X-ray treatment is rarely any use

Excision of the papillomata.—The most artistic method of treating papillomata is only possible when they can be felt In rare cases a tiny shotty swelling can be palpated near the nipple, indicating a papilloma of some size in one of the large ducts

By a small incision 1–1½ in long radiating from the nipple over the swelling, the duct, usually dilated and sometimes dark from the blood

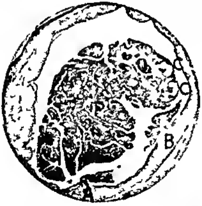


A B

Fig 343 —Excision of a palpable papilloma together with a length of the duct in which it lies

(a) The breast with the papilloma A and the m l rated corresponding lobe (b) The retracted radial skin incision with exposure of the ducts before removal of a length of duct including the papilloma.

within it, may be exposed in the dense tissue in which it lies By careful dissection it is followed up until it begins to ramify in the breast It is verified that the shotty swelling previously felt lies within the duct Artery forceps are applied to the duct on either side of the swelling which is then excised with the portion of duct in which it lies (Fig 343) Owing to the density of the fibrous tissue around the ducts, the operation is a troublesome and finicking one requiring good eyesight and miniature instruments



A B

Fig 344 A —Duct papilloma becoming carcinoma

P papilloma lying in a dilated duct which is surrounded by old adventitious fibrous tissue the result of bacterial duct infection A B pedicles of two papillomata which have fused together C C dilated veins the rupture of which caused the hæmorrhage

Fig 344 B —The earliest stage of duct carcinoma of the breast. High power photograph of the pedicle B

At A A are two groups of epithelial cells embedded in cicatricial fibrous tissue in the wall of the duct These foci represent the beginning of malignant infiltration.

Papillomata of this kind may be entirely innocent or upon section the substance of the papilloma may be found infiltrated by its own epithelium and the growth though it has not yet infiltrated the physiological tissues of the patient who produced it is nevertheless a potential carcinoma For such a papilloma the name precancer

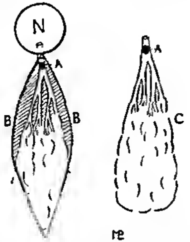


Fig 345 —The operation of lobectomy for papilloma affecting one lobe only but not accurately localizable

N nipple B B retracted radial skin incision. A papilloma C lobe of the breast after removal

seems appropriate In still other cases incipient infiltration of the patient s tissues may be found beneath the base of attachment of the papilloma which is clearly then an early carcinoma (Fig 344)

The operation for a papilloma which cannot be accurately localized is illustrated in Fig 345

CHAPTER XIV

OPERATIONS FOR ABDOMINAL INJURIES*

By G GREY TURNER

CONTUSIONS

CONTUSIONS of the abdominal wall owe their importance to the possibility of some underlying injury to the viscera Any intra abdominal organ may be ruptured without the association of superficial injury and as all abdominal injuries give rise to more or less shock it may be very difficult to make a diagnosis When there is a penetrating wound the abdomen must be opened and explored at the earliest possible moment If treatment is to be successful rupture of a hollow viscus must be recognized early and the surgeon must not wait for signs of developing peritonitis to help in the diagnosis

Rupture of a solid viscus often gives signs of internal hæmorrhage and the organ may be identified by a corresponding injury to the ribs in the case of the liver and spleen Sometimes injury of the intestine is associated with signs of internal hæmorrhage when the mesentery is torn But if the diagnosis of rupture of a hollow viscus is to be made in time for successful surgical intervention it can be arrived at only by continual observation at the bedside In all these cases there is shock and for perhaps two hours it may be impossible to decide whether the injury is severe or not But with appropriate treatment shock tends to pass off if uncomplicated so that if after two hours the condition of the patient is not improving some deep-lying injury may well be suspected Evidence is obtained from the facial appearance the respiration abdominal examination and the pulse rate The most important physical signs are rigidity local tenderness fluid in the flanks and above all free gas in the peritoneal cavity as shown by the replacement of liver dullness by a tympanitic note X ray examination helps to determine the presence of smaller amounts of free gas Emphysema of the abdominal parietes at an early stage before organismal invasion can play a part is pathognomonic

Indications for operation —If in spite of treatment shock does not pass off and the patient s condition does not improve an exploratory laparotomy must be carried out without loss of time The prognosis in these cases depends on two factors—(1) the extent of the injury (2) the lapse of time between injury and operation

The mortality in unoperated cases of injury to the hollow viscera is approximately 100 per cent Even if delay has occurred and

* See also Enterectomy and Intestinal Anastomosis, p 903.

peritonitis is established, the case need not be regarded as hopeless, although mortality is very much higher in late cases, success is occasionally attained even if the condition is desperate. Lacerations and contusions of the solid viscera are also very serious.

General considerations.—It is most important in all cases that the patient should be subjected to a careful general examination. Too often an obvious and perhaps gross lesion determines the attitude of the surgeon, whereas a more complete examination would show, it may be, the hopeless nature of some other injury or at least its great importance. Generally speaking, it is a mistake to operate during the period of profound shock which so often follows these injuries. If this cannot be overcome by ordinary routine measures—of course, including blood transfusion—then it is highly unlikely that any operative interference will be successful. The same applies, but to a lesser degree, to the consequences of hæmorrhage: unless the patient shows some evidence of recuperative power it probably means that the loss which has already occurred is too severe to permit of recovery.

It is most important that the manipulations of the surgeon should not be impeded in any way, and for this reason it is usually best to employ general anæsthesia, for which purpose gas oxygen ether or even open ether is satisfactory.

The first principle which should guide the surgeon in the conduct of the operation is a thorough and adequate exposure. For general purposes nothing is better than a midline incision, but there should be no stint to its length. In the first instance the incision ought certainly to extend the whole of the distance from the umbilicus to the pubes, and it may very often with advantage be enlarged upwards as far as the costal margin. The surgeon should not hesitate either to make a second incision or to make a cross cut from the original incision if, by so doing, he can facilitate the manipulations which may be necessary as life-saving measures. After opening the abdomen it is essential to determine the full extent of the injuries, for that will help the surgeon to decide what measures to employ. For instance, an isolated laceration of the intestine may suggest a resection with anastomosis as the ideal and safest method. Should there be other associated lesions, such as multiple tears in the mesentery or injury to the spleen or kidney, it may be necessary to take the risk of simply suturing the bowel tear rather than excising the damaged segment. It is not necessary to display either heroic or brilliant operative procedures unless they will more safely tide the patient over a great emergency. The surgeon must also remember the wonderful reparative power of the peritoneum, especially in adolescents. When there has been bleeding into the peritoneal cavity it is wise to remove the larger clots but it is not necessary to attempt to clear out all the blood. In perforative lesions, where infection has already started, an effort should be made to aspirate or mop up free blood in order not to leave ponds that might form abscesses later.

The real difficulties in wounds and bruises of the intestine are met

when the injuries are multiple In these circumstances it may be easy to remove the whole of the damaged bowel, but the surgeon must never forget that massive resection involving more than one-third of the intestine is likely to interfere permanently with nutrition further, it may be that the surgeon must stay his hand because of the very serious condition of the patient It is remarkable how damaged and bruised intestine will recover if the areas involved are simply tucked in and overstitched Sometimes a damaged piece of intestine

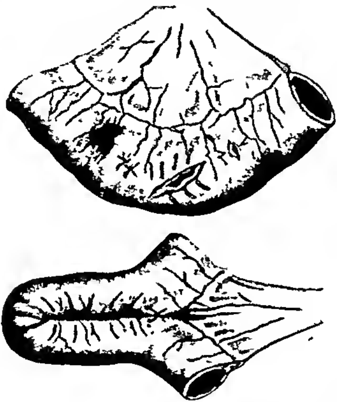


Fig 346 —The piece of bowel in A shows multiple small tears and is much bruised. The tears are sutured and as a further protection, the bowel is then folded on itself and tacked together as shown in B

may be sutured against an undamaged coil, the latter acting as an admirable graft (Fig 346) This may be done even when the mucous membrane cannot be very securely sutured

Technique.—As the patient is usually in a condition of shock, unnecessary delay or exposure must be avoided All preparations must be completed before the patient is brought to the operating-theatre, which should be at a temperature of 70° F The trunk and limbs are warmly clad, a subcutaneous or intravenous glucose saline is administered and if there is restlessness, omnopon or morphia and atropine is given hypodermically An apparatus should be ready for

the administration of continuous glucose saline solution during the operation A preliminary whole blood or plasma transfusion may be of great value

When shock is severe the skin preparation should be deferred until the patient is anæsthetized Many different methods are probably equally efficient, but I have complete confidence in 1 in 20 carbolic acid in watery solution Even in the presence of gross dirt this lotion is used with soap for preliminary cleansing and shaving Afterwards the surface is again washed with clean 1-in 20 carbolic and a piece of lint soaked in the solution is laid over the operation site while the towels, etc, are being arranged Care must be taken that the patient does not lie in a pool of the lotion, as blistering is then very likely If a differential diagnosis has been made the incision should be so placed as to give the best exposure Otherwise the abdomen is opened in the middle line from the umbilicus to the pubes When the peritoneal cavity is opened, free gas or blood may escape It is necessary to have a definite plan of action, so that no time may be wasted and nothing overlooked this is determined by what is found on opening the abdomen If blood only escapes—and this is most often the case—examine in this order the omentum especially at the greater curvature of the stomach, by direct vision, the liver, the spleen, and the kidneys, by palpation If no injury is found, the mesentery is examined, beginning at the ileo cæcal region and going upwards If still no injury is disclosed, the blood is mopped out of the abdominal cavity and a further detailed search made—bladder, stomach duodenum, pancreas

The small intestine is more often injured than the large, and both more often than the stomach If free gas escapes, therefore, the surgeon picks up the small intestine at the ileo-cæcal junction and rapidly examines it from below upwards, the assistant returning the gut after inspection, so that only a small loop is exposed at a time If no injury is found the large intestine is examined from the cæcum, and when the transverse colon is reached the stomach and duodenum are examined, and then the rest of the large gut If there is fæcal extravasation, the intestinal injury is generally quickly discovered It is curious how often the injured segment of intestine is found in the neighbourhood of the incision

INJURIES OF THE LIVER

If the diagnosis is made before operation, it will be possible to select the incision so as to obtain a wide exposure If the subumbilical exploratory incision has already been made it will be necessary to extend it above the umbilicus and perhaps add division of the upper right rectus abdominis muscle The oblique incision of Kocher, as used for the surgery of the biliary tract (p 796), also provides adequate exposure The late Mr Carson was in favour of a transverse incision through the right rectus abdominis at a level of 2 in above the

umbilicus, it gives an excellent exposure of the upper or lower surface of the right lobe, or of the gall-bladder and biliary ducts, and can if necessary, be extended across the middle line It is easily closed, and subsequent straining by vomiting or coughing does not tend to draw the edges apart as in vertical incisions A loin support, as used in gall bladder operations, and the reversed Trendelenburg position are both useful adjuncts

Treatment of liver injuries.—The indication for operation is hæmorrhage If when the liver is exposed, the hæmorrhage has

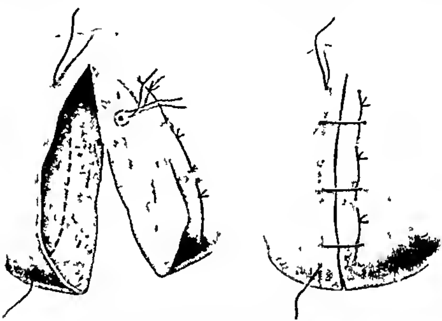


Fig 347 —Suture of liver with a buried catgut strand to support the sutures of apposition

On the left side of the wound the buried strand has been passed with a large half-curved needle on the right the strand has been introduced in three sections on a fully-curved needle. On the cut surface is shown the method of surrounding an open hepatic vein with a purse-string

ceased the injury unless extensive, should be left alone If there is a wide laceration, with or without active bleeding the raw surfaces should be approximated by catgut sutures deeply placed so as to coapt the surfaces as far as possible Some difficulty may be experienced as the liver is friable and the stitches are apt to cut through This is best met by using thick catgut which is passed beyond strands of catgut buried in the liver on either side of the tear (Fig 347)

If the liver is much contused, and sutures will not hold the tears or lacerations which bleed must be packed with gauze the free end being brought through the abdominal wall and left for several days, as early removal will very likely re start the hæmorrhage

Injuries to the *gall bladder* and *bile tract* are uncommon It is better treatment to remove a ruptured gall bladder than to suture it, because there is certain to be some bruising of *indefinite extent* and

leakage may occur after suturing Injury to the *common bile duct* requires suturing and drainage by a tube passed down to the site

For further details of operations for liver injuries *see* p 755 and for injuries of the ducts p 832

INJURIES OF THE SPLEEN

Injuries of the spleen produce severe hæmorrhage and as the organ is well protected it is generally damaged in crushes with fracture of the ribs and perhaps injury to other viscera

If a diagnosis is made, the incision should be planned as for splenectomy (*see* p 870) As a rule the safest course is to remove a ruptured spleen owing to the difficulty of controlling hæmorrhage by suture in an organ which is very friable and is made still more so by the injury

INJURIES OF THE PANCREAS

The pancreas is rarely damaged alone though instances are recorded of injury by crushes gunshot wounds and stabs In the majority of cases other organs especially the stomach are injured at the same time and the pancreatic injury is often not diagnosed before operation The operation consists in opening the abdomen in the median or paramedian supra umbilical line exposing the pancreas and suturing the tear The gland is reached by tearing an opening through the gastro colic omentum and turning up the stomach which may also be gently retracted upwards Unless the splenic artery has been divided there is not usually great hæmorrhage A stab or a bullet wound may be closed by a purse string suture but a more considerable tear must be approximated by a series of interrupted sutures The divided surface must be drawn together by interrupted sutures When the injury has almost completely torn across the gland it will probably be best to remove the sequestrated caudal portion In all cases the lesser sac must be drained and if the pancreas is much lacerated or contused the drain usually a rubber tube should be brought from the vicinity of the injury Gauze packing should be avoided whenever possible as its removal is so likely to produce pancreatic fistula As Jordan Lloyd pointed out contusions and minor lacerations are frequently followed by inflammatory effusion which is localized to the lesser sac as the result of occlusion of the foramen of Winslow This is one of the forms of pseudo cyst of the pancreas For cure of this condition drainage is essential

INJURIES OF HOLLOW VISCERA

The stomach owing to the thickness of its walls and its comparatively sheltered position is less often injured than the intestines and in both small and large bowel the portions most liable to injury are those which are least mobile—i e in the small intestine the upper part of the jejunum and the lower part of the ileum in the large intestine the cæcum and ascending colon The splenic flexure

however which is the least mobile part of the large intestine is well protected under the ribs and is rarely injured In all cases the liability to rupture is greater if the viscus is distended with gaseous or fluid contents at the time of the injury

It follows that most of these ruptures are of a bursting character from within outwards and they are not infrequently multiple In the stomach the common site is the lesser curvature in the intestine the antimesenteric border In other cases the mesentery is injured and there is liability to hæmorrhage to necrosis of the bowel owing to the cutting off of the blood supply or to perforative peritonitis if the mesenteric tear extends into the mesenteric border of the gut

Treatment —The choice of method depends upon two factors—(1) the extent of the injury (2) the condition of the edges of the rupture

In the stomach gross injuries rarely come to operation as they are so frequently associated with laceration of the liver or spleen and death occurs almost at once—as for instance in a buffer accident—or the patients never recover sufficiently from the primary shock to hold out the least prospect of success from intervention Hæmorrhage into the peritoneum and the escape of gas on handling the stomach suggest the site and the wall of the viscus in the vicinity is seen to be much bruised It is always wise to open the lesser sac by carefully tearing through the gastro-colic omentum and if it contains blood or fluid of any sort to make a careful search for an injury on the posterior wall In the smaller ruptures it is always possible to suture the rent The edges should not be pared unless there is much laceration The rent is closed by catgut suture passed through all the coats and this suture line is buried by a superimposed continuous Czerny Lembert suture If the rupture is quite small it may be closed by a purse-string As in the majority of these cases the stomach is not empty at the time of rupture it is well to provide a pelvic drain

Isolated injuries to the duodenum are relatively rare which is fortunate for the accident is very serious and attended by a high mortality Sometimes the second part is ruptured and the tear may be extra peritoneal and be associated with extravasation with consequent cellulitis which rapidly spreads and is nearly always fatal Very rarely a localized abscess may follow and eventually lead to the formation of an extraperitoneal duodenal fistula When the tear is intra peritoneal the irritating contents of the duodenum are poured into the belly and a rapid peritonitis is the inevitable result Tears of the duodenum will probably be across the lumen and may be particularly difficult to repair because of extension into the retroperitoneal tissue The necessary suturing may so interfere with the lumen of the bowel that an accompanying gastro-enterostomy may be necessary

Injuries that are entirely retroperitoneal are difficult to diagnose for the symptoms are anomalous Pain in the right upper quadrant with rigidity distension and vomiting slowly develop After twelve hours or thereabouts the general condition is often out of keeping with the physical signs for the patient looks very ill and is obviously

toxic, with an icteric tinge and higher temperature than is usual in abdominal cases Even on opening the abdomen the condition is not obvious The peritoneum may appear almost normal or may contain just a little clear fluid with a small amount of lymph near the injured part There is retroperitoneal hæmorrhagic extravasation on the right side, extending into and around the meso colon The cellular tissue is œdematous and crepitant and there may be some fat necrosis

To expose this portion of the duodenum, the stomach and colon are lifted up as in the early stages of gastro-enterostomy An incision is made through the posterior fold of the meso colon towards the right and, by blunt dissection and gauze stripping the injured area is cleared Care must be taken not to injure the colic vessels It may be difficult to expose the tear for the purpose of repair but the laceration must be seen in its full extent before sutures are applied The inner wall should be approximated by sutures passed mattress fashion, to invert the edges into the lumen of the bowel A continuous suture is then used for the inverted edge and to complete apposition along the whole tear In spite of the absence of peritoneum, additional sutures of the Lembert type should be passed on the outside If the extraperitoneal tissues are grossly infected drainage should be provided For this purpose an incision should be made in the right flank down to the retroperitoneal space which is opened up towards the site of injury by blunt dissection with the finger a rubber tube or strand being placed in the track

When the rupture is at the duodeno jejunal junction the bowel may be torn so near its origin that it may be well nigh impossible to make an end to end repair The best course to pursue under the circumstances is a matter of grave difficulty Moynihan* boldly closed the proximal end of the duodenum and implanted the open end of the jejunum into the stomach so that all the bile and pancreatic juice had to regurgitate into the stomach before it could reach the intestine The patient is said to have enjoyed perfect health until his death on the 104th day This was due to perforation caused by the Murphy button used to make the anastomosis But this method cannot always be relied on, and a very determined attempt should be made to restore the continuity of the bowel even at considerable risk It is usually possible to mobilize the proximal end from the retro peritoneal bed into which it retracts and to make an end-to-end anastomosis If that cannot be done, the upper end of the distal jejunum may be implanted into the stomach and an end-to-side anastomosis made between the divided proximal end of the duodenum and the intestine leaving the stomach

Intestinal injuries vary from a split in the serous or sero muscular coats to a complete rupture of continuity In partial ruptures, if the case is seen early, there is often surprisingly little extravasation because of the pouting of the mucosa through the rent and the temporary cessation of peristalsis

* Brit Med Journ 1911 I 1138.

Injuries of the serous and sero-muscular coats must be repaired by suturing with fine chromic catgut or silk to prevent subsequent adhesions At the same time a very exact examination must be made to exclude an injury to the mucosa for severe bruising may lead to necrosis

If all the coats are perforated and the amount of damage is small

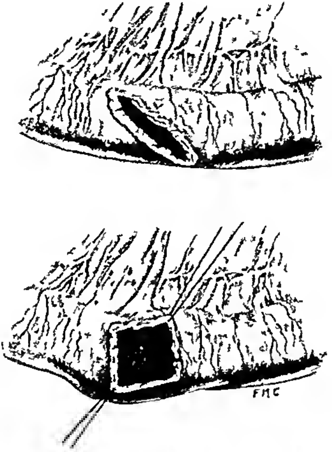


Fig 348 —Rent in bowel sutured in transverse axis to avoid narrowing the lumen

the rent should be sutured transverse to the long axis so as to avoid constriction of the lumen (Fig 348) A continuous suture is employed joining all the coats and this is buried by a Lembert suture

If the injury is more extensive and there is much laceration or contusion of the bowel wall it is usually much safer to carry out a resection and anastomosis than to suture a large rent Particularly is this the case if the mesentery is injured and it should be the rule that a generous rather than a minimal resection should be done It is however true that suture has a much lower mortality than excision and should be chosen whenever it will suffice

A point of importance is the treatment of multiple ruptures. The condition arises, of course, more often in gunshot wounds than in civil practice. The surgeon must decide whether multiple resections should be done, or a single resection to include all the injured areas, or whether a combination of repair and resection is to be preferred. Time is necessarily a factor of real importance in dealing with injuries of such severity. It will take longer to do three or two resections than one, and unless the length of uninjured intestine which must be sacrificed is too great, it is better to do a single resection to include all the damaged intestine. But this is not always possible, owing to the distance between the ruptures, and multiple resections may be undertaken with confidence if the surgeon is constantly doing intestinal suture operations. It is never good practice to sacrifice more intestine than is absolutely essential to ensure success Many enormous

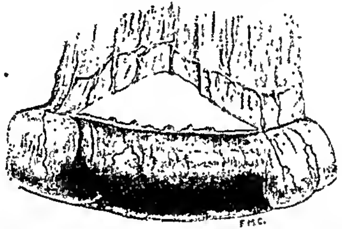


Fig. 349.—Laceration of mesentery. Bowel torn away. Resection necessary.

resections have been carried out with recovery and little apparent interference with health, but the converse is also true. Probably six feet is the limit beyond which it is unwise to venture.

In these cases it is essential to have a very free exposure and to examine the site of the lesion carefully. Sometimes a piece of bowel is completely separated from its mesentery over an area of several inches (Fig. 349), and in such circumstances resection must be carried out. Very rarely a portion of the intestine may be torn loose from all its connections and may lie free in the peritoneal cavity and, unless discovered and removed, it remains a focus of serious infection likely to destroy the good result of any other measures that may have been adopted. Experience of war casualties has taught great respect for the recuperative power of the small bowel, and when lesions are multiple the surgeon need have no hesitation in adopting what, in civil life, might be looked upon as timid conservative measures. It is much safer to tuck in many small rents and to overstitch doubtful areas than it is to engage in multiple resections or to sacrifice too

large an area of intestine (Fig 350) Occasionally the bowel which has been patched in this way may look as if it would be a source of obstruction but as a matter of fact this rarely occurs as the channel is always bigger than it appears and in any case a very small lumen will suffice for the fluid contents of the small intestine When there is real and anxious doubt the surgeon can add a small lateral anastomosis to his repair Two small perforations may sometimes be conveniently converted into one which can then be sutured in

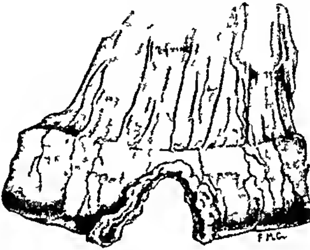


Fig 350—Almost complete severance of bowel but suitable for repair by suture

the transverse axis (Fig 351) In finishing these cases time should not be wasted in closing the abdominal wall in layers and even in muscular subjects through and through sutures of strong silkworm gut or of silk are all that is necessary In the after treatment it is important not to be in a hurry to get the bowels to move for bruised and damaged intestine should not be urged to activity by powerful purgatives

Great difficulty and much added danger arise in injuries of the gut *which have not a complete peritoneal covering such as the greater* part of the duodenum and some parts of the colon

Retroperitoneal rupture in large intestine—This condition is usually associated with other injuries such as laceration of the kidney Even when it occurs alone the patient very rapidly shows signs of retroperitoneal cellulitis It is important to remember that if an easy route to the surface is provided suture of the bowel is not essential and it may be much wiser to make a fæcal fistula at the wound by stitching the bowel margins to the skin Such a fistula often closes spontaneously or it may be assisted later by temporary colostomy or it may require direct interference Even if a satisfactory suture can be made a drainage track to the surface should always be provided as

leakage often occurs, and is sometimes not recognized until the appearance of cellulitis or a localized abscess. After drainage, a fæcal fistula often occurs; this may close spontaneously or may require an extensive resection.

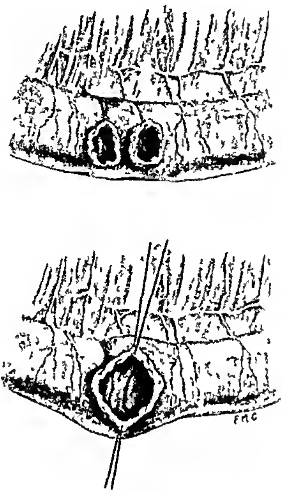


Fig 351 —Two perforations converted into one and prepared for suture in transverse axis

RUPTURE OF THE URINARY BLADDER

Intraperitoneal.—These ruptures occur from direct blows on the abdomen when the bladder is full. The tear is usually situated on the postero superior surface. The accident usually happens quite apart from injuries to the pelvis, and indeed when the bladder is torn as the result of fracture of the pelvis, the rupture is generally extra-peritoneal.

The diagnosis is readily made from the characteristic symptoms of shock, hypogastric pain and tenderness, frequent desire with inability to micturate, the evidences of increasing peritoneal irritation with

signs of fluid in the flanks and the withdrawal of only a small quantity of blood stained urine by catheter

Treatment —Laparotomy should be carried out as soon as possible A vertical incision is made in the midline below the umbilicus the peritoneal cavity is opened and blood and urine are swabbed away or removed by the suction apparatus If the tear is not obvious it may be found by the fingers passed down behind the viscus When the rent is low down the patient should be put up in the Trendelenburg posture which greatly facilitates repair Two guide sutures are inserted one on each side of the rent taking up the serous and muscular coats only and these are used to lift the bladder towards the incision These guides are a great aid to exposure and may render an otherwise difficult intervention comparatively easy The rent is closed by catgut sutures silk should not be used for it tends to work loose into the bladder cavity where it may form the nucleus of a calculus If necessary very frayed edges may be trimmed Two layers of suture should be employed the first takes a good hold of the bladder wall but does not penetrate the mucous membrane the second should be a continuous stitch on the peritoneal aspect Sometimes it is very difficult to close a rent securely when it is situated low down on the posterior wall or there may be so much bruising and hæmorrhagic infiltration that the closure is uncertain In such circumstances a rubber tube should be placed in the recto vesical pouch and brought out at the lower end of the abdominal incision the patient being nursed in the semi Fowler position for the first few days A catheter should be passed *per urethram* for continuous drainage and should be left *in situ* for a week Each morning and evening the lumen should be gently irrigated to keep it free from blood at first and later from mucus or phosphates

Results —Here again the time limit is the most important factor If the operation is done in the first twelve hours the mortality should not be above 39 per cent but after that time there is a mortality of about 70 per cent

Extraperitoneal ruptures are much more likely to be associated with fracture of the pelvis In these cases there is considerable hæmorrhage as well as extravasation of urine into the pelvic cellular tissue and this gives rise to local swelling above the pubes and either inguinal ligament A few hours after the injury such swellings are associated with marked blood discoloration But unless the lesion is also intraperitoneal there is no peritonitis though there may be considerable meteorism Sometimes it is difficult or impossible to guide a catheter into the bladder and in these circumstances the viscus has probably been torn from the back of the triangular ligament and the prostatic urethra completely cut across In the intraperitoneal variety fluids can very readily be injected for they pass through the rent in the bladder into the peritoneum whereas in the other variety more urine may be drawn off but attempts to inject the bladder give

rise to great pain and increase the suprapubic swelling This injury also demands prompt operation A midline incision is made above the pubes not deliberately opening the peritoneal cavity The extravasation of blood and urine becomes apparent as soon as the muscles are separated It is then necessary to remove the clots after which the rent in the bladder may be seen or felt though it may be very difficult of access Should it be easily seen it can be closed by suture but this is not essential and free drainage to the surface is all that is really necessary, though suture may shorten convalescence When the bladder has been torn away from the triangular ligament it is essential that a catheter should be passed *per urethram* and guided into the bladder by the surgeon's fingers working from the abdominal incision By this means the prostate can be approximated to its normal position at the back of the triangular ligament and fixed there by one or two strong catgut sutures The catheter also ensures that the alignment of the urethra is accurate Even when it has been possible to suture a rent and to pass a catheter into the bladder, it is essential to leave an ample suprapubic drain in the cellular tissue If there is any possibility of an associated intraperitoneal lesion this can be demonstrated by a finger passed into the bladder (through an incision if no tear exists) and through the rent into the peritoneum In these circumstances the abdominal incision must be enlarged so that the peritoneal surface of the bladder can be inspected It may also be necessary to open the peritoneum if the question of some associated injury to other viscera arises In late cases infection may already have occurred, and in these circumstances it is only essential to remove clots and debris and to provide ample facilities for drainage During convalescence the patient should be treated in the Fowler position

Results.—When free drainage is provided the prognosis in this type of injury is good so far as life is concerned When the prostatic urethra is severed a troublesome stricture or deviation may develop and there is a tendency to recurrent suprapubic fistula

GUNSHOT WOUNDS OF THE ABDOMEN IN WARFARE

The war of 1914–1918 provided a wealth of material for the investigation of gunshot wounds of the abdomen, and much was written on the subject Towards the latter part of that conflict there was general agreement on the principles of treatment and in analysing 965 cases, Sir Cuthbert Wallace* added to the work previously done by the late Sir George Makins Speaking generally, it was accepted that the expectant treatment which was the rule after the South African War had given place to operative measures and much of the success attending these interventions resulted from the early treatment in advanced operation centres (C C S) and from the creation of abdominal hospitals In the mobile warfare of the present campaigns

* Lettsomian Lectures to the Medical Society of London 1917 and *Brit Journ Surg* April, 1917 iv 679

and among air raid victims abdominal wounds seem to be less frequent The mortality in the small number of cases recorded is admittedly high because of the great difficulty of bringing the injured to operation centres within a reasonable time When circumstances have made it possible to carry out the principles of treatment established in the war of 1914–18 the results have been comparable Gordon Taylor* found that the general mortality of abdominal cases submitted to operation in the present war is 50 per cent With the exception of the large bowel the recovery rate was rather higher than in 1914 18 He states† that blood tranfusions and chemotherapy proved of great value

Under the system which evolved between 1914 and 1918 most cases arrived between six and ten hours after injury and statistics proved that while up to six hours the chances were in the patient s favour after that period they were always against him The limit of success was thirty six hours in cases requiring resection of the small gut or suture of the stomach or colon Hæmorrhage was the chief cause of early death and peritoneal sepsis later Side to-side and oblique wounds were more dangerous than antero-posterior and wounds from the back more dangerous than wounds from the front A special danger lay in buttock wounds penetrating the abdomen and wounds of the descending were more dangerous than those of the ascending colon owing to the former being covered by the jejunum which was often injured simultaneously

The order of frequency of wounds of the viscera was found to be (1) small gut (2) colon (3) liver (4) stomach (5) kidney (6) spleen (7) bladder (8) pancreas

Indications for operation —It is well to wait an hour or two after admission before operation is carried out The patient has time to recover from the journey shock can be combated and a better idea obtained of the necessities of the case and the scope of the operation required The *pulse* is the best guide a rapid pulse of 120 or over which does not fall is a direct indication for intervention Very few patients whose pulse-rate is over 120 recover though the mortality has been much reduced by preliminary blood transfusion *Vomiting* is of less significance *Rigidity* is very constant but may occur in thoracic injuries *Hæmorrhage* though surmised often cannot be diagnosed with certainty unless in great amount and *pain* while constant varies much in degree extreme pain with board like rigidity nearly always means an intestinal wound If the abdominal wall is penetrated a viscus is probably injured and exploration is imperative but admittedly it is not always easy to be sure Emphysema of the parietes at an early stage i e before gas forming organisms could be the cause is a sure sign of perforation of a hollow viscus Experience and the views held by the surgeon must decide the question of operation It should be remembered that the bolder surgeon will get the worse operative mortality though he will have the satisfaction of saving a few desperate cases

* Bradshaw Lecture *B M J Journ* March 14 194 i 346

† *Surg Gyn and Obst* Feb. 16 194[illegible] Issue 375

Operative treatment.—Speed in operating is important but it must not be at the expense of efficiency The surgeon must know just what to do and must be systematic in carrying out his work Exposure is all important, and generally speaking the primary incision should be in the middle line When the injury is found to involve the liver or the spleen a cross cut from the median incision dividing the rectus may greatly facilitate exposure On opening the abdomen the first indication is to arrest hæmorrhage its origin from the omentum or the mesentery may be obvious or welling up from either flank may suggest the liver or the spleen as its source But wherever its origin it must be found and dealt with as a first step Similarly a perforative injury may at once declare itself, otherwise the intestine must be systematically searched Retro peritoneal injuries are easily over looked but a hæmatoma behind the peritoneum especially if crepitant means a perforation which may be of the duodenum or some part of the large bowel

Stomach —Operation should be done in all cases through a median incision It is not necessary to excise the wounds In uncomplicated cases the mortality in Wallace s series was 5 27 per cent in com plicated cases 77 8 per cent

Small intestine —The abdomen is freely opened by a median in cision Blood is mopped out and hæmorrhage controlled The small intestine is inspected from the ileo-cæcal valve upwards the gut being returned to the abdomen as each fresh section is withdrawn If a small wound is found it is sutured at once provided the bowel for 6 in on each side is healthy The search continues and similar small rents may be treated in the same way If a severe laceration of the intestine or mesentery is found, it should be wrapped in warm gauze until the exploration is finished

The stomach is then examined, and lastly the colon It is the exception for extravasation to occur in injury of the small gut though common in large gut wounds under war conditions when the bowels have so often to be neglected If laceration either of the gut or of mesentery is considerable it may be necessary to resect but this increases mortality, and it is better to repair the injury by suture when ever possible, even if it causes narrowing of the gut * End to end or lateral anastomosis may be used and in Wallace's cases lateral anasto mosis gave rather better results but end to-end anastomosis was perhaps more generally performed Primary short-circuiting was abandoned Drainage is unnecessary

The mortality in Wallace s series of uncomplicated cases was 65 9 per cent in complicated cases 74 1 per cent Injury to the duo denum was more fatal than injury to the ileum, and this more fatal than injury to the jejunum

* Owen Richards s later writings (1918) Fraser and Drummond (80 per cent. mortality in resection 50 per cent in suture) Walters and Lockwood agree but F Gordon Bell of Edinburgh obtained a 46-per-cent. recovery rate in 30 resections *Quoted by Gordon Taylor Brit. Med Journ.*, Oct 22, 1921 ii, 641

Large intestine —A paramedian incision is the most suitable because of the probability that the small intestine also is injured This is especially likely in wounds of the descending colon Where a diagnosis is made of injury to the hepatic or splenic flexures it is better to make a transverse incision as this allows easy access to the kidney liver and spleen In the transverse colon the wound should be sutured if possible and if that cannot be done the tears may be converted into an artificial anus

In the ascending and descending colon the position is complicated by the possibility that the wounds may be retroperitoneal If this occurs in the ascending colon the wound should be sutured and in addition shut off from the peritoneal cavity by suturing the anterior surface of the bowel to the abdominal wall drainage being arranged by an independent incision in the loin In the descending colon the same treatment may be adopted or an artificial anus may be made More artificial ani had to be made in wounds of the splenic flexure and descending colon than elsewhere A proximal colostomy was little used and cæcostomy was not successful although Gordon Taylor (*loc cit*) says it has proved of inestimable value in his hands in large-intestine resections

The mortality in uncomplicated cases was 58 7 per cent , if an artificial anus had to be made the mortality advanced to 73 5 per cent but of course this step was only resorted to in severe cases The prognosis is much graver if the retroperitoneal space becomes infected (John Fraser s colon septicæmia)

Rectum —The rectum may be injured by buttock wounds or wounds fracturing the pelvis The great risk is septic absorption Wallace was in favour of transverse colostomy if suture is impossible or if on account of friability the sutures are likely to tear out Of 21 cases only 7 recovered

Liver —If no other organ is injured gunshot wounds of the liver are best left alone If hæmorrhage makes operative interference imperative the wound in the liver should be either sutured or packed

Spleen —The spleen should be exposed by a subcostal or rectus incision If hæmorrhage has ceased the organ may be left alone Gauze packing will sometimes suffice to stay hæmorrhage from the outer surface Excision should be done only if the organ is much lacerated or its vessels injured The mortality in uncomplicated cases was 50 per cent in complicated cases 63 6 per cent

Kidney —An incision should be made in the loin and the wound sutured or packed and drained The organ should be excised only if the injury is very severe The mortality was 18 per cent

Pancreas —This organ is seldom injured alone the stomach is usually involved Severe wounds are rapidly fatal lesser injuries are usually complicated by local inflammation and drainage is essential

Bladder—Gunshot injuries may be intraperitoneal extra peritoneal, or both, and in almost half the cases they are complicated by wounds of other viscera, generally small intestine Intraperitoneal wounds are, as a rule, easily sutured and suprapubic drainage is unnecessary, but a catheter should be retained for twenty-four hours The mortality in uncomplicated cases is 56 per cent, mostly from shock and hæmorrhage Wallace had no success in complicated cases

GUNSHOT WOUNDS IN CIVIL LIFE

These are usually caused by small arms or by shot-guns and often at short range In the circumstances there may be great damage to the parietes as well as to the abdominal contents Shot-gun pellets may be scattered in all directions and the wad may lodge in the abdomen The latter must be removed as it will almost certainly be associated with infection and may cause peritonitis or keep up a sinus for years, but it is not necessary to trouble about the small shot as long as any visceral lesions are attended to All that has been said about abdominal injuries in general and gunshot wounds in warfare apply to those in civil life, but there is the advantage that, as a rule surgical aid is summoned much earlier and can be carried out in more suitable surroundings It is essential to work with ample incisions and to make a very thorough and complete investigation before the *first* discovered injury is dealt with The lesions are frequently multiple and one overlooked may completely spoil the result of an otherwise brilliant piece of surgery

CHAPTER XV

OPERATIONS ON THE STOMACH

By SIR JAMES WALTON, K.C.V.O

Anatomical and physiological considerations.—At one time much stress was laid upon the shape and position of the stomach, detailed descriptions being given of the various divisions of the organ and the relations of these divisions to surrounding viscera. It is now realized, owing to the work of Hurst, Barclay and others, that all such divisions are largely artificial and that the stomach is a tubular viscus formed of living and contracting muscle which continually alters its shape owing to the amount of its contents and the peristaltic action of its walls. Its position is also extremely variable even in health, its height within the abdomen being dependent upon the tone of its muscular walls. The amount of this tone may not only differ considerably in two individuals both of whom are free from disease but it may alter from time to time in the same individual (Fig 352). Generally speaking, the tonic stomach shows a vertical or cardiac portion and a pyloric or horizontal portion. The cardiac part lies to the left of the middle line in the epigastrium and in the left hypochondrium. Its upper portion or fundus is less contractile than the lower and even when the viscus is empty, is generally shown by X rays to contain a little gas. The lower part is more contractile and shows true peristaltic movements. It is usually known as the tubular portion. The œsophagus enters at the junction of these two parts on the right-hand side. The pyloric portion is not only differentiated by its horizontal position, but there is a notch on the lesser curvature at the junction of the two parts, known as the incisura angularis of His, from which a well defined band of circular muscle passes to the greater curvature, this muscle being known as the transverse band or middle sphincter. It is peristaltic throughout and is somewhat artificially divided into a pyloric antrum and a pyloric canal, the latter showing a greater development of circular muscle and a corresponding increased power of peristalsis. At its termination the circular muscle is considerably increased to form the pyloric sphincter, which may cause a projection into the lumen and is sharply differentiated from the relatively thin circular muscle coat of the duodenum. During an operation the stomach is atonic and the

Fig 352.—The stomach

a The shape of the empty stomach as deduced from radiograms b The shape of the distended stomach and the atonic stomach as seen at operation

above differentiations are not apparent, the whole organ having the curved and slightly distended appearance of the moderately dilated viscus. (Fig. 352, B.)

In its greater part the stomach is covered by peritoneum. It may indeed be considered to lie between the two anterior layers of the great omentum which again fuse above the lesser curvature to form the lesser or gastro-hepatic omentum. Immediately behind it, therefore, lies the lesser sac, separating it from the pancreas, mesocolon and duodenum. In adult life, however, the lesser sac is often in part obliterated, so that the mesocolon containing the middle colic artery

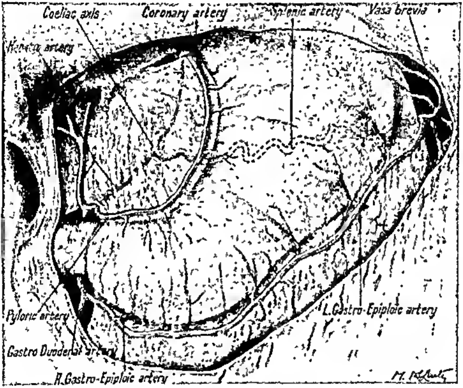


Fig. 353.—Blood supply of stomach.

may be fused with the anterior layers of the gastro-colic omentum or even with the posterior wall of the stomach. Just below the entrance of the œsophagus, the two layers of the lesser omentum separate so that a triangular area of the upper part of the lesser curvature is left uncovered by peritoneum.

The vessels of the stomach consist in the main part of two vascular loops running along the lesser and greater curvatures. That on the lesser curve is formed by the coronary artery arising from the cœliac axis, and the pyloric artery arising from the hepatic, while the loop on the greater curve is formed by the right gastro-epiploic passing from the gastro-duodenal artery, and the left gastro-epiploic arising from the

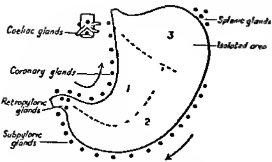


Fig 354 —The lymphatic fields and glands of the stomach

splenic The two arches so formed lie about half an inch distant from the greater curvature and run closely applied to the lesser curvature, and from them a large number of branches are given off at right angles to pass to both the anterior and posterior surfaces of the stomach (Fig 353) It must be remembered that all these vessels arise behind the lesser sac and pass around its borders to reach the stomach hence when the coronary artery has to be divided at its origin as is necessary in the operation of gastrectomy for carcinoma of the stomach, the posterior layer of the lesser sac has to be divided In addition to these loops, the vasa brevia pass to the fundus along the gastro splenic omentum from the splenic artery

The lymphatics of the stomach are of considerable importance in the treatment of carcinoma of the stomach There are three lymphatic fields (Fig 354) Carcinoma most frequently arises in the two lower fields which must, therefore, be completely removed, but the area of the fundus will be free unless involved by direct spread The glands are chiefly placed along the curvatures In the greater curvature the path of lymphatic flow is from the fundus to the pylorus, and in the lesser curvature from the pylorus to the œsophagus In operations for carcinoma of the stomach all the glands around the pylorus, and especially those on the head of the pancreas, those along the two curvatures and those around the cœliac axis must be freely removed

From the surgical point of view the most important physiological functions are the secretions of acid and of the anti anæmic factor of Castle Peptic ulceration is dependent upon the secretion of acid and

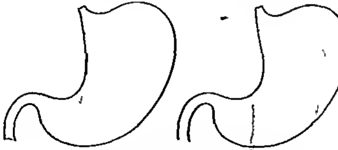


Fig 355 —The gastric secretion.
a The area secreting the anti-anæmic factor of Castle (*after Meulengracht*) b The area secreting acid (*after Miyagawa*)

operations for its cure are designed to reduce the acidity, either directly or indirectly On the other hand, an extensive gastrectomy for carcinoma or ulceration, by removing the greater part which secretes the anti anæmic factor, may produce a severe primary anæmia The acid-secreting area probably varies in different individuals, and in those in whom this area is more extensive there is a greater tendency for ulceration and for the recurrence of ulceration after operation The distribution of the acid-secreting cells has been studied by Miyagawa, it is larger than would be expected from the frequency with which complete achlorhydria follows partial gastrectomy (Fig 355, *b*) The area of the cells secreting the anti anæmic factor has been investigated by Meulengracht (Fig 355, *a*) It is interesting to note, however, that even after extensive partial or even complete gastrectomies, primary anæmia is rare On the other hand secondary anæmias, probably due to interference with gastric digestion, are not uncommon

CONGENITAL PYLORIC STENOSIS

Congenital pyloric stenosis is an interesting condition in which there is gross hypertrophy of the circular muscle of the pylorus which is entirely concentric, the outer diameter of the pyloric canal never being increased and indeed often decreased Within the greatly narrowed canal the mucosa is thrown into longitudinal folds which obstruct the lumen the stomach is dilated and its muscular wall much hypertrophied in an attempt to overcome the obstruction

The lesion is much more common in males In my own series of 84* cases, 69 were males It is generally seen in first children Often, however, several members of the family may be affected and examples have been reported occurring in both twins The change is almost certainly a congenital hypertrophy, for symptoms usually appear within three weeks of birth, when the hypertrophy is already enormous, and cases have been reported where it was present at birth The stomachs of all these patients are identical in appearance the lesion has a familial incidence it does not disappear after relief of the obstruction by, for example the performance of posterior gastro-enterostomy, and it persists after death A certain amount of spasm may be supra-added, but this cannot be the cause of the hypertrophy, for the period after birth is so short and, as far as is known, spasm of involuntary muscle never leads to hypertrophy, e g cardiospasm and Hirschsprung's disease If congenital, it would be expected that minor examples would persist and be found at a later age and there is considerable evidence that such is the case (*See* acquired pyloric stenosis (p 780))

Symptoms and physical signs.—The infant usually appears normal at birth, but within a short period begins to vomit The vomiting increases in amount until most of the food is returned and the vomited material is forcibly ejected The food is often changed and a slight temporary relief may occur but the symptoms soon return The baby at first does not gain weight and soon rapidly loses The skin becomes

* Owing to war disturbances the personal statistics in this article only include cases to the end of 1938

thin, wrinkled and inelastic, the eyes are sunken and there are all the symptoms of dehydration (Fig 356) Constipation is very evident On examination the child is wrinkled and shrunken, the upper abdomen is distended the stomach can be felt dilated, and gastric peristalsis is visible On careful palpation an elongated tumour can often be felt in the region of the pylorus Some observers are of the opinion that this can be felt in every case and that a positive diagnosis should not

Fig 356 —Congenital pyloric stenosis before operation Age 4 weeks weight 7 lbs Birth weight 8¼ lbs

be made in its absence This is probably correct, but with the presence of forcible vomiting and a dilated and peristalting stomach it is evident that there is a mechanical obstruction and whether this be due to a pyloric stenosis or a duodenal obstruction becomes a matter of lesser importance as both conditions will probably require operative interference

Indications for operation —At one time medical treatment was almost wholly employed but was found to be followed by a very high mortality some 50 to 75 per cent of hospital cases failing to survive and even those that did live often developed very poorly Of late however better results are claimed by careful dieting and the use of atropine and its derivatives and the latest drug Eumydrin The chief indication for surgical interference is loss of weight or failure to gain weight Operation should wherever possible always be carried out before the patient is seriously dehydrated

Choice of operation —At one time gastro-enterostomy divulsion and even pylorectomy were performed for the relief of the condition but these operations so dangerous in infants have been entirely replaced by a form of pyloroplasty known as Rammstedt s operation which can be carried out in five or six minutes has a very low mortality and gives most satisfactory results

Preparation for operation —Nearly all these patients have been under medical treatment before operation is instituted They have been carefully dieted and probably stomach washes have been employed In any case it is wise to have the stomach washed out just before the patient is sent up to the theatre It is our custom at the London Hospital to carry out no other preparation Just before the operation the clothes are arranged and the child is bandaged to a small crucifix ready for the anæsthetic If very wasted 100 c c of saline solution is given subcutaneously In some clinics this is performed as a routine procedure but it is our custom only to do it in bad cases Very rarely if the child is extremely ill we give intravenous saline with 5 per cent glucose this usually being given with a special needle through the anterior fontanelle into the longitudinal sinus

Choice of anæsthetic —There is a considerable divergence of opinion whether these cases should be operated upon under a local or a general anæsthetic At the London Hospital we have carefully tried both methods and are using local anæsthetics less and less frequently It has been our opinion that the results are not so good that the child tends to be more collapsed and that the wound does not heal so well One or two of these children have also shown definite toxic effects from the anæsthetic It is therefore our custom now either to give very small doses of warmed ether vapour or gas and oxygen anæsthesia It is essential to have an anæsthetist who is experienced in this branch of work The anæsthetic is only commenced when the patient is brought into the theatre and when the surgeon and his assistants are ready

Operative technique —As soon as the patient is anæsthetized the abdomen is exposed As the arms and legs are bandaged to the crucifix the belly is easily accessible The skin is prepared either with 2 per cent iodine solution or with plain spirit A high 2 in vertical incision is made ½ in from the midline and extending downwards from the right costal margin This is carried directly through the anterior aponeurosis and the rectus It is my custom in these small children not to displace the rectus for the risk of injuring this muscle in so small an incision is very slight The posterior aponeurosis and peri toneum are opened in the same line In these young children practically the whole of the incision lies over the liver which prevents any of the viscera extruding The right lobe is now lifted up and the stomach withdrawn this usually presents no difficulty The viscus is then drawn over to the left until the pylorus is exposed and the presence of the pyloric thickening made manifest The duodenum is grasped between the finger and thumb of the left hand immediately below the thickening the limits of which are thus felt and made evident With a scalpel an incision ½–¾ in long is made along the thickened pyloric canal midway between the lesser and greater curvatures (Fig 357) The length of the incision depends upon the extent of the pyloric mass With the blunt end of a Watson Cheyne dissector the circular

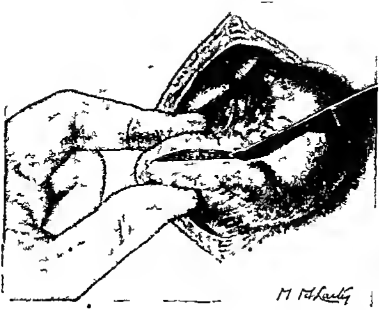


Fig 357 —Rammstedt s operation Incision of peritoneal coat

muscle fibres are gently torn asunder until the mucosa bulges between them (Fig 358) Great care must be exercised where the incision approaches the duodenum for the mucosa projects up as a fornix round the lower end of the muscle and may easily be injured The

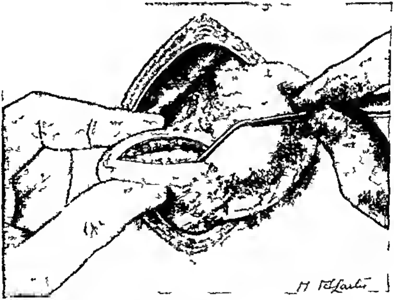


Fig 358 —Rammstedt s operation Division of muscle with blunt dissector

incision is gently swabbed to make sure that there is no hæmorrhage and the stomach is allowed to slip back into the abdomen If there should be a point bleeding it should be ligatured and if the mucosa at the fornix has inadvertently been wounded a small catgut stitch is used to close the opening The wound is closed in layers the posterior sheath and aponeurosis being sutured with intestinal catgut two tension sutures being passed through the abdominal wall the anterior aponeurosis being also closed with a continuous suture of catgut and the skin with interrupted silk sutures A dressing is applied and the patient returned to bed

Post operative treatment —The treatment after operation is very important If the patient is dehydrated 100 c c of normal saline with 4 per cent glucose may be given subcutaneously and this may if necessary be repeated in six hours In the majority of cases however this is unnecessary and our routine treatment is to give 1 dr of 7 per cent glucose with water by mouth beginning three hours after the commencement of the operation and continued every half hour for seven doses Milk is given six and a half hours after operation Wherever possible the expressed mother s milk is used 1 dr being given for the first three doses The intervals and the doses are then gradually increased so that by the twelfth feed 4 dr are being given every hour and a half and by the sixteenth feed the dose is increased to 1 oz which is given every two hours If it is impossible to obtain the mother s milk Cow and Gate food mixed with equal quantities of water is given in the same doses and at the same intervals The chief danger to these patients is the development of diarrhœa and since this danger appears to be increased by a possible infection in a general ward it is our custom to send these babies home on the third or fourth day They are brought back to be seen in the ward and to have the stitches removed on the twelfth day

Fig 359 —Congenital pyloric stenosis one year after operation Same case as Fig 356

Results of operation —There is perhaps no condition in modern surgery which gives so much satisfaction These patients before operation are wizened miserable little creatures

often on the point of death As the result of operative treatment the majority are not only restored to normal but develop into fine bonny children who, curiously enough, are often above the average standard of height and weight (Fig 359)

The results of operative treatment have been *steadily* improving In the earlier days such interference was only sought when the children were on the point of death, and the mortality was high Rammstedt's operation can be completed in five to seven minutes and carries with it a much lower operative risk than any of the previous procedures Now that its value is appreciated, cases are sent for early operation and the mortality is becoming very small Of my 84 cases, 80 have been treated by the Rammstedt operation with a total of 15 deaths, but in the last series of 31 cases there has only been one death The first four cases I operated upon were treated by posterior gastro-enterostomy and three of them died These figures are in accord with those of the more recently published statistics *L E Holt* states* that in an early series 1901–1911 there was a mortality of 58 per cent in 24 cases, but in a later series, 1915–1916, the mortality had dropped to 23 per cent Perhaps the most interesting of recent series is that published by T H Lamman and T I Mahoney † This consisted of a series of 425 cases operated upon at Boston in the years 1915–1931, and all treated by Rammstedt s method In the first 125 cases the mortality was 10 4 per cent, in the second 150 cases 7 per cent and in the last 150 cases only 2 per cent They considered that the anæsthetic of choice was ether by the open method, and laid great stress upon the importance of pre-operative and post-operative care

PEPTIC ULCERATION OF THE STOMACH AND DUODENUM

There is every reason to believe that the operative treatment of peptic ulceration is one of those branches of surgery which will ultimately disappear with increasing knowledge In spite of a vast amount of clinical and experimental work the cause of these lesions is ill understood There is an overwhelming amount of evidence that hyperacidity, either congenital or acquired, is a very important factor, that gastritis is a frequent if not a constant precursor and concomitant of ulceration, and that infection giving rise to the gastritis may possibly reach the stomach with the food and certainly is, on occasion, carried to the walls of the stomach from remote foci by the blood-stream Neuro muscular changes giving rise to abnormalities of emptying or to areas of vascular spasm appear at times to be important factors, and evidence is being accumulated that metabolic errors and endocrine faults may have a bearing, but the interaction of these different factors and the methods of controlling them are not at present fully known and thus, although recent knowledge has greatly increased,

* *Journ Amer Med Soc* 1917 lxviii, 1517

† Congenital hypertrophic stenosis of the pylorus, *Surg Gyn and Obst* No 2, Feb, 1933 lvi 205

the rational treatment of preventing peptic ulceration or of curing it in its early stages by altering these factors is not yet certain and surgery is therefore often the sole means at our disposal of saving life and giving the patients a more comfortable and a safer existence

Indications for operation —With the growth of medical and pathological knowledge there has been a great change in the accepted form of treatment of these lesions Some thirty five years ago surgery was only considered with the onset of some complication such as perforation hæmorrhage or stenosis This period was followed by the rapid growth of surgery till it reached its zenith some twenty years ago when many surgeons taught that all peptic ulcers whether acute or chronic in young or old and whether producing mild or severe symptoms should be subjected to operation and the profession of medicine was sharply divided into those who believed in operation and those who advocated medical treatment In later years evidence has been produced to show that many ulcers can be cured by medical treatment and that the indiscriminate use of surgery does not give satisfactory results At the same time surgeons and physicians are in much closer accord as to which cases should be treated medically and which should be subjected to surgery There are still some divergences of opinion and this is bound to be so for the surgeon s advice is sought for the medical failures and the physician s aid is asked for those patients whom the surgeon has failed to cure and each is impressed by the other s failures

All would agree to-day that with the possible exception of a few cases of severe hæmorrhage no operation should be performed for acute ulcerations and erosions If they occur in the course of a severe septic infection elsewhere or of a septicæmia attention should be directed to the primary lesion whilst those occurring without any such manifest focus will yield to adequate medical management It was for the chronic indurated ulcer that surgery was most frequently advocated but there is no doubt that many such ulcers can also be cured and to-day no experienced surgeon would advocate operation until the patient has had an adequate course of medical treatment it may be said that the main indication for surgery is the failure of such treatment The definition of a failure must however be considered a little more fully A wealthy patient living a comfortable and sheltered life may be cured of the acute symptoms and kept free from all recurrence by adhering to a strictly limited diet and living a carefully controlled life so that treatment can be regarded as successful A labourer with a similar lesion cannot exercise the same control A stevedore having to earn his living in the docks cannot subsist on Benger s food peptonized milk eggs and custard he has to make his dinner of meat bread cheese and possibly an onion or lose his work so that in his case the medical treatment is a failure and surgical aid must be sought His only criterion of a cure is can he eat his ordinary food ? And can he carry out his ordinary work ?

The other indications for surgical interference are the presence of

certain complications Severe hæmorrhage in the opinion of some surgeons demands immediate operation but this question will be considered later The frequent recurrence of less severe hæmorrhages may endanger the patient s life and demand operation but these are only an indication of the failure of medical treatment If the ulcer perforates into the peritoneal cavity the only hope of saving the patient s life lies in immediate operation The presence of much scarring leading to stenosis and mechanical obstruction is a complication which can only be remedied by surgical measures If there be any suggestion in the symptoms or physical signs that the ulcer has undergone a carcinomatous change operation should be performed at the earliest date Many lesions become inoperable because valuable time is wasted in making a probable diagnosis a certainty It is to-day generally agreed that some 10 per cent of chronic ulcers become carcinomatous Moreover the biggest danger that has arisen from the wider use of medical treatment of peptic ulcers is that a primary carcinoma in its early stages may be mistaken for an ulcer and operation postponed until the lesion is long past the possibility of successful removal

Choice of operation —There is a considerable divergence of opinion on the procedure best suited to bring about a cure in the different types of peptic ulceration Indirect operations may be performed which aim at neutralizing the acidity of the stomach and by overcoming this important factor bringing about a cure of the ulcer or the ulcer bearing portion of the stomach may be excised but if this is to be successful sufficient of the stomach wall must be removed to take away the greater portion of the acid secreting cells so permanently reducing the acidity The indirect operations have a low immediate mortality but a higher recurrence rate while the partial gastrectomies are more serious and dangerous operations but are less likely to be followed by a recurrence although they may give rise to other complications in later years No dogmatic statement can be made in the present state of our knowledge for the primary mortality will of necessity depend upon the skill of the individual surgeon One who makes a practice of performing partial gastrectomy for all cases will not only become more skilled with that method but using it for the less serious cases will have a low primary mortality whereas a surgeon who performs the more palliative operations will probably have a very low mortality for that group but having reserved the partial gastrectomy for the serious and advanced cases this operation in his hands will have a high death rate The only test is for each surgeon to consider the whole of his cases treated by every method and to determine what is the total mortality Very few such statistics have been published moreover the risk of late complications can only be determined with any accuracy after many years observation The literature on this subject is enormous and figures have been published strongly supporting both methods Generally speaking it is the custom on the European continent to perform a partial gastrectomy for nearly every variety of peptic ulcer while in England and the United States the more con

servative view is held, although even in these countries there are some surgeons who follow the Continental practice

For these reasons it is useless to quote large numbers of published figures and I shall therefore only discuss my own methods, my reasons for using them and the results I have obtained thereby

Duodenal ulcer

This variety of chronic ulceration is the one in which high acidity is so marked a factor In the great majority of cases the acid is raised well above the normal and it is, therefore, in them that the two methods of treatment may be sharply distinguished —

1 Operations which are devised to neutralize the gastric acidity by intimately mixing the bile and pancreatic secretions These operations may or may not be combined with local treatment of the ulcer

2 Those that permanently reduce gastric acidity by excising the greater part of the acid secreting area of the stomach

In the first group are included posterior and anterior gastro-enterostomy, and excision combined with gastro enterostomy or gastro duodenostomy, while in the second group are the operations of partial gastrectomy

Until a few years ago gastro enterostomy was the operation universally advocated and it was generally believed that in its modern forms it gave a low mortality, easy convalescence and satisfactory results Of late, however, the end results have been questioned There is perhaps no more satisfactory operation in surgery than a posterior gastro-enterostomy performed for a stenosing and obstructing ulcer of the duodenum, but it has been thought by many that the results are not so good in the absence of stenosis and that with young people the results are often unsatisfactory Unfortunately the ease of its performance led to its use by many who were untrained not only in the technical steps of the operation but in the selection of correct cases for operation

In retrospect it is fair to say that most of the young patients with ulcers without stenosis, which gave bad results, should have been treated medically The bad results were due not to the wrong operation but to the performance of any operation at all The chief objection which has been raised to this procedure is the fancied frequency of gastro jejunal ulceration after it Much has been written on the incidence of this serious complication by Lewisohn, Finsterer, von Haberer, Von Eiselsberg and, in this country, Pannett, Ogilvie and others, who regard the incidence as between 15 and 20 per cent, a view which is also held by many physicians If this were so it would indeed be a very big indictment of the operation, for there can be no question that gastro-jejunal ulceration is a very serious complication and that the operation for its cure carries with it a high mortality My own experience does not, however, support this view All my cases have been most carefully followed up in a special follow-up department which has been in operation since 1919, so that none of

the cases has been lost The actual figures show that in 896 cases of duodenal ulcer the incidence of gastro jejunal ulceration was just under 4 per cent, and I am confident that these figures are correct

On the other hand partial gastrectomy does reduce the acidity more completely and lessens the incidence of gastro jejunal ulceration but it does not, as was at one time believed entirely remove it In my own cases of extensive duodenal ulcers treated by partial gastrectomy, there has only been one case of marginal ulcer, but of the 128 cases of gastro-jejunal ulcer which have come to me for further treatment there were 6 in which the previous operation bad been a partial gastrectomy This is an incidence of 4 6 per cent of the total numbers of gastro jejunal ulcer but I have no data from these figures by which I can ascertain its incidence in a group of cases treated by partial gastrectomy Although partial gastrectomy probably does lessen this danger there is no doubt that it carries with it a higher mortality, which in the many reported figures averages 5–10 per cent and these results are obtained by the most expert surgeons performing it as a routine method even for simple ulcers In order to reduce its mortality many surgeons are modifying the partial gastrectomy, and are leaving the pylorus behind and taking away less of the stomach This is the procedure in the popular operation of Finsterer and there is no doubt that many of these resection operations are no longer true partial gastrectomies but are approximating to the old sleeve resections an operation which was abandoned because of the frequency of recurrent ulceration and it seems likely that they will carry in the future a big risk of local recurrent ulceration

My opinion, based on this experience therefore is that it is unjustifiable at present to replace an operation with a mortality (in my hands) of 1–2 per cent by one with a mortality of 5–10 per cent in order to avoid a complication which occurs in no more than 4 per cent of the cases The correct procedure however for every surgeon is to investigate his own cases most carefully and to carry out that technique which in his hands he finds gives the lowest immediate mortality and the highest freedom from future complications

My own practice is to perform these operations as follows —

1 Gastro enterostomy —This is used as a routine operation Wherever possible the posterior method is performed If there is a short mesocolon or if it is laden with a good deal of fat, the anterior anastomosis is carried out The short circuit is combined with embedding the ulcer and occlusion of the pylorus for this prevents the possibility of a hæmorrhage from the base of the ulcer, which might have been initiated by manipulation at the operation

2 Partial gastrectomy —This operation is reserved for cases with a very high acidity and no stenosis and generally for younger people who undoubtedly show a higher incidence of gastro jejunal ulceration Recently Hermon Taylor has shown a relationship between hyper trophic gastritis and the future appearance of gastro-jejunal ulcer He

found it in several of my cases, by gastroscopy before operation, and in these patients I performed a partial gastrectomy Generally, some form of the Billroth I method is used which restores the stomach more to its normal shape, but if there is the slightest difficulty in approximation or in suturing the duodenum, the Polya operation is substituted

3 **Excision plus gastro-duodenostomy**—This operation I very rarely use It is frequently performed by many American surgeons, who claim good results but in my own hands there have been few cases in which the ulcer could have been excised with a low risk which would not have been equally satisfactory after the simpler operation of gastro enterostomy It is true that by excising the ulcer and making a wide opening between the stomach and duodenum satisfactory results are often obtained and there is of course no risk of a gastro jejunal ulcer but my own experience has been that there is a considerable risk of local recurrence

Gastric ulcer

With ulceration of the stomach the effect of hyperacidity is less marked My own experience has been that in most of these cases the acidity was within the upper limits of normal, although all observers are not agreed upon this point, but it is certain that it is not as a rule raised to the same degree as in a duodenal ulcer Nevertheless, there is still the same difference of opinion as to whether operative treatment should be directed locally to the ulcer or whether a partial gastrectomy should be performed—carried out in this case with the idea of removing the whole of the ulcer bearing portion of the stomach

At one time gastro-enterostomy alone was the operation of choice It was felt that with this measure a certain amount of rest was obtained for the ulcer and the acidity was reduced It was soon found, however, that, although some ulcers were completely cured there was a high percentage of recurrence, which is usually given at about 40 In the small series of cases in which I performed this method alone, there were over 8 per cent of recurrences, and I have treated 20 cases where a lesser curve ulcer developed after the performance of gastro-enterostomy for a duodenal ulcer It has, therefore, been abandoned as the routine treatment of ulcers of the lesser curvature of the stomach Nevertheless, there are certain cases of very large and deep ulcers in which a partial gastrectomy would be a formidable undertaking or, indeed, might be impossible owing to the high situation and size of the ulcer In these cases it is often well worth while performing an anterior or a posterior gastro-enterostomy, but the patient should always be carefully followed up afterwards In a certain percentage a complete cure may result, but in the remainder there is only temporary or incomplete improvement, although at a second operation the size of the ulcer may have so diminished that a resection is quite possible It is often stated that the drawback of this measure is that if the ulcer at the time of the first operation had been carcinomatous the operation would be of no avail If it is only

employed for these very extensive ulcers and carcinomatous changes had been present a radical cure would already have been impossible

Local operations for the resection of the ulcer alone have frequently been performed A V excision was introduced by Rydygier and was at one time very popular but it is of course theoretically unsound If an ulcer would develop in the normal stomach it would be much more likely to develop in the scar of a resection In a very small series of cases where I had performed this operation 50 per cent recurred If however it be combined with a gastro enterostomy I believe it is one of the most satisfactory of all operations for a small and mobile ulcer It cannot be adequately employed if the ulcer is big or has much induration around and it is technically very difficult if the ulcer is situated high up on the lesser curvature In my own series there have been 262 simple ulcers and 31 cases of hour glass constriction treated by this procedure In this group the mortality was 3 per cent and there was only one recurrence in the whole series It is I believe preferable to combine the gastro-enterostomy which in these cases runs along the greater curvature with a temporary occlusion of the pylorus

For certain simple ulcers which are less accessible the lesion may be destroyed with the actual cautery This method is eminently suitable for a small ulcer high up on the posterior surface The stomach can be turned up and the ulcer destroyed with the cautery the opening is then sutured with catgut the pylorus is temporarily occluded with a running mattress suture of silk and a posterior gastro enterostomy is performed This operation has been very widely carried out by Balfour at the Mayo Clinic with very satisfactory results

In the rare cases where the ulcer is situated on the middle of the posterior surface and is not easily accessible **Mayo's transgastric resection** may be useful the stomach is opened the ulcer excised from within the opening sutured with catgut and a gastro enterostomy performed

From time to time it has been advocated that the ulcer itself should be embedded with a purse string suture and the gastro-enterostomy then carried out It is probable that the area of the ulcer owing to the constriction in large part necroses and the method has come to be known as that of **stitch resection** It is more uncertain than the wedge resection or cautery resection but this effect is probably produced when a perforated ulcer is embedded or a bleeding ulcer is controlled with the insertion of stitches for it is a remarkable fact that when a perforated ulcer of the lesser curvature of the stomach has been sutured and a gastro-enterostomy performed recurrence is very rare whereas as already mentioned gastro-enterostomy for a non perforated ulcer has a high percentage of recurrence It is my own custom to reserve this method for cases of perforation and for a few cases of hæmorrhage

At one time the so-called **method of sleeve resection** was very popular By this method a segment of the stomach bearing the ulcer was

excised and an end end union carried out My own experience has been unsatisfactory, and I believe that the operation is theoretically incorrect If the segment removed is small the operation has the same drawbacks as has a V-resection not combined with gastro enterostomy, and even if larger it is in fact only a badly-performed partial gastrectomy which does not remove the whole of the ulcer bearing area nor reduce the acidity with any certainty Some of the modern forms of partial gastrectomy or resection of the stomach are approximating, in the small amount removed, to this old operation and therefore, in my view, are unsatisfactory

Partial gastrectomy is almost universal with most Continental and some British surgeons My objection to it as a routine operation is that it seems physiologically unjustifiable to remove seven eighths of the stomach for an ulcer which may be only ½ in in diameter It carries with it a higher mortality than the V-resection and is associated with a greater danger of subsequent anæmia For large ulcers where a V-resection would cause considerable deformity, it is the only feasible method In such cases the upper portion of the stomach may be united to the open end of the duodenum or to the side of a loop of jejunum Owing to the risk of subsequent anæmia from the bigger resection, and the higher mortality associated with these operations, many surgeons are advocating that the stomach be divided proximal to the pylorus and the operation then completed by direct end-end union

In certain cases in which the ulcer is close to the œsophagus a gastrectomy which removed the ulcer would in fact have to be a total resection, an operation which carries with it a very high mortality In such cases a gastrectomy below the ulcer has been advocated for, the acidity being thereby abolished, the ulcer will heal To my mind, however, the more satisfactory method is that in which the gastrectomy is performed in this way below the ulcer but the lesser curvature of the remaining portion of the stomach which contains the ulcer is then excised, the lesser curve is sutured and the partial gastrectomy completed in the usual manner This is known as Pauchet's operation and I have found it extremely satisfactory In one or two cases the ulcer has been so high that after excision it has been necessary to pass an œsophageal tube so that the suturing of the lesser curvature does not constrict the œsophagus, but in spite of this technical difficulty the results have been very satisfactory

It is my own custom, therefore, to select operations for peptic ulcer of the stomach in the following manner

For relatively small mobile ulcers on the lesser curvature, a V-resection is performed and the opening in the stomach closed The pylorus is temporarily occluded with a running-mattress suture of silk and a posterior gastro enterostomy is performed, the opening of the anastomosis being placed on the posterior surface of the stomach and running along the greater curve so that, wherever possible, half the opening is proximal to the line of excision and half is distal

For ulcers so large that local excision would cause considerable deformity for widely adherent ulcers and for those in which there is the slightest suggestion of carcinoma a partial gastrectomy is the operation of choice

It was my previous custom to perform a Billroth I type of anastomosis if only three-quarters of the stomach was removed and to use a Polya gastro jejunostomy for the larger resections An appreciation of the fact that the larger the portion of the stomach removed the greater the mobility of the cardiac end owing to the wider division of the gastro splenic omentum has led me in later years to use the Billroth I method in nearly all cases the main counter indication being a narrowed duodenum

For relatively small ulcers high up on the stomach a cautery resection and gastro enterostomy is the method of choice but if the ulcer be larger and nearer the œsophagus Pauchet s modification of a partial gastrectomy is selected If the ulcer be very big and high up a simple gastro enterostomy is performed and the patient is then carefully watched and the progress of the ulcer controlled by X ray investigation If it persists a second operation may be performed in a year or more by which time a resection or partial gastrectomy is usually feasible

By selecting the cases in this way it will be found that the more palliative operations give a relatively low mortality and with gastric ulcers the risk of a marginal ulcer is almost negligible but the partial gastrectomies which are reserved for the more serious cases will have a higher mortality than many lists that have been published and it is for this reason that I feel that selected statistics of one method of treatment are of but little value In my own series there have been 588 cases of ulcer of the lesser curvature and 90 cases of hour glass stomach The total mortality by all methods was just over 8 per cent but in the group treated by excision and gastro-enterostomy it was only 3 per cent Gastrectomy which was used for very large ulcers often very adherent gave in this group a mortality of a little over 10 per cent I believe that these figures are a fair estimate of the results that are obtained by surgeons practising in this branch of surgery

Preparation for operation—Many of the patients who come for operation will have had a course of medical treatment and will have been in bed on a strict diet and proper drugs and thus will have been prepared for operation If they have been up and about they must be carefully prepared In most cases the blood should be examined and it is my own custom if the hæmoglobin is low and operation is urgent or in any case in which it is below 70 per cent to give a blood transfusion otherwise it may suffice to keep them at rest in bed for a week on careful diet and with some iron preparation If the patient is at all wasted and dehydrated fluid should be given and my own preference is to administer this per rectum 1 oz of glucose in 1 pint of water being given at 12 hourly intervals Many surgeons advocate the intravenous administration of fluid but by this method

it is easy to give too much and to increase the risk of postoperative pulmonary œdema It is always advantageous to give glucose either by mouth or per rectum Even if the patient is apparently in good health no operation should ever be performed unless there has been at least one complete day's previous rest in the nursing home or hospital Nothing is more to be deprecated than the habit of taking a patient in late overnight and operating early next morning

On the night before operation the abdominal wall should be shaved and the skin prepared It may be painted either with iodine or with plain spirit, the only benefit of iodine over spirit is that it shows clearly where the material has been applied The abdomen is then covered with a sterile towel a second application being made on the morning of the operation, and a third on the operating table The ordinary meals which the patient is able to take are given up to and including lunch, if the operation is to be performed early next morning In the evening a small meal of Benger's fluid, vegetable soup or milk is given, and after that nothing before the operation

Choice of anæsthetic.—Many different forms of anæsthesia are used and equally good results are claimed by the different methods The choice will depend upon the skill of the anæsthetist On the Continent, where specialist anæsthetists are unusual and many of the anæsthetics are given by students or nurses, the surgeon usually employs some form of infiltration or local anæsthetic If a general anæsthesia is employed, the surgeon should always make use of an anæsthetist who is conversant with his methods It is in big operations of this sort that team work is so essential It is my own custom always to employ the same anæsthetist, he examines the patient the day before operation, and I leave the choice in his hands Usually a small dose of omnopon and scopolamine is given three quarters of an hour before operation, in some cases only one hundredth of a grain of atropin is used I find that to-day the majority of anæsthetists have abandoned the use of avertin or evipan, and if they use these drugs at all give only a minimal dose to make the patients unconscious until they reach the theatre The actual anæsthetic is either warmed ether vapour or gas and oxygen, or a combination of both Today, many prefer pentothal My own experience has been that a skilled anæsthetist can give these drugs so satisfactorily that not only is complete relaxation obtained but the risk at operation is greatly diminished

Operative technique. Incision —Many incisions have been advocated Of late there seems to be a tendency to revert to the midline incision To my mind this is very unsatisfactory There is only a single layer of aponeurosis to suture and I have seen many cases where there has been a wide divarication of the recti after it Those who employ it claim that it is much quicker, but an operation of this magnitude should never be made a race against time Some employ the transverse incision, and although this usually unites satisfactorily I think it causes an unnecessary amount of injury to the abdominal

wall In my own hands the upper paramedian incision with displacement of the rectus outwards has been very satisfactory A five or six inch vertical incision is made through the skin an inch to the right of the midline all bleeding is controlled and skin towels are then clamped to the subcutaneous fat (Fig 360, A and B) Special forms of forceps for this purpose are unnecessary, the ordinary small Spencer Wells forceps can be used and thus the multiplication of instruments is avoided The anterior aponeurosis is divided in the line of the skin incision and the internal flap dissected off the rectus muscle In most cases this separation is easy but in a second operation a careful

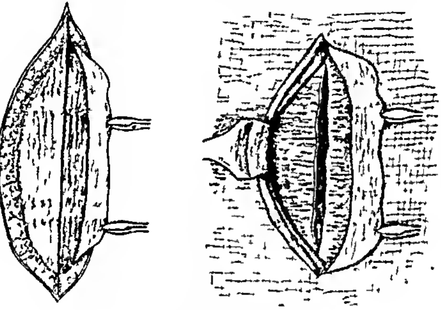


Fig 360 —Paramedian incision

A Anterior aponeurosis divided in line of skin incision and internal flap dissected up B Skin towels applied rectus retracted out posterior aponeurosis divided in line of skin incision

dissection may be required The rectus being retracted, the posterior aponeurosis is divided in the line of the skin incision so that when sutured this incision is completely covered by the muscle As a general rule the right paramedian incision will be found most serviceable even when the ulcer is high up on the lesser curvature It will always give free access to the duodenal stump, and if the fundus of the stomach is far up it is made easily accessible by the division of the falciform ligament and ligamentum teres For very high ulcers where a view of the œsophagus is necessary, the device first demonstrated to me by Prof Grey Turner of dividing the left coronary ligament and turning the left lobe of the liver to the right will be found extremely useful As soon as the abdomen is opened a general investigation is carried out

It is always essential to examine first the viscera thought to be

healthy, for as soon as the known lesion is found the surgeon's attention may become so concentrated upon it that he is likely to forget the rest of the abdomen. In cases of gastric and duodenal ulcer, the hand should be inserted into the pelvis, the uterus and ovaries in females rapidly examined, the cæcum and appendix felt, the pelvic colon examined for the presence of diverticula or a possible carcinoma, and the gall-bladder and pancreas examined The hand is then slipped over to the left and the condition of the spleen investigated. The stomach is withdrawn and attention given to the duodenum and lesser curvature

When the operation is completed the posterior aponeurosis is held

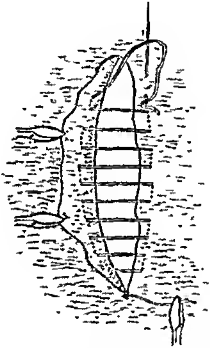


Fig 361.—Method of suturing peritoneum and posterior sheath

up with Spencer-Wells forceps and a strip of thick rubber about 7 in. by 4 in, which is easily made from the inner tube of an old motor tyre, is inserted and adequately covers the intestine. The posterior sheath is then sutured with continuous catgut, a most satisfactory grip being obtained by a running-mattress suture, the right side of the aponeurosis being picked up from within and the left side from without (Fig 361) The rectus is held back in position by one catgut stitch loosely tied If the patient is fat, or in all cases of carcinoma, two or three stout tension sutures should be inserted which pass through the skin, anterior sheath and rectus The anterior aponeurosis is sutured with a running suture of catgut and the skin with sutures of fine silk, and a dry dressing is then applied.

Gastro-enterostomy

In a supposed case of duodenal ulcer the lesion must be identified beyond doubt by the presence of induration scarring of the peritoneal surface and the characteristic speckling around its edges If the duodenum be mobile and its lumen patent, the ulcer should be embedded sufficiently to occlude the duodenum temporarily This can be best accomplished by the passage of a running silk mattress suture, the so-called Kelling-Mayo suture (Fig 362) If there be much stenosis or the duodenum be fixed and adherent, this stitch is unnecessary

Wherever possible a posterior anastomosis should be chosen This gives most satisfactory results and is less likely to be followed by postoperative obstruction The great omentum, the transverse colon and the stomach are drawn out of the wound and turned upwards on

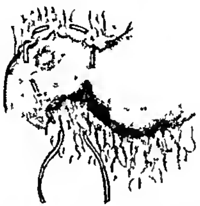


Fig 362 —Kelling Mayo suture for embedding duodenal ulcer or temporarily occluding pylorus

the towels lying over the thorax, thus exposing the under surface of the mesocolon This is opened by a vertical incision in a bloodless space usually between the left and middle colic arteries, the so-called space of Riolan The opening is enlarged until it is 3½–4 in in length and the posterior wall of the stomach is grasped at the lesser curve with the right hand and at the greater curve with the left hand (Fig 363) The portion of stomach so held is withdrawn and rotated counter clockwise An assistant applies a rubber covered clamp to its base, the handles being on the patient s left By this means the stoma will be placed vertically on the posterior wall of the stomach If preferred it may be made to incline to the right or left with no impairment of the immediate or late results, but the vertical opening usually lies more easily

The upper end of the jejunum is then picked up and the duodeno-jejunal junction clearly seen and examined for abnormalities The contents of the first eight inches are ' milked away, and a rubber-covered clamp is applied with the handles towards the patient s left,

and about 3–4 inches from the duodeno jejunal junction, so as to engage a loop of intestine of a similar length to the part of the stomach already engaged At one time it was advocated that the clamps should be applied as close to the duodeno jejunal junction as possible (no loop operation) The presence of tension is contrary to all surgical principles, and therefore a loop only of sufficient length to avoid

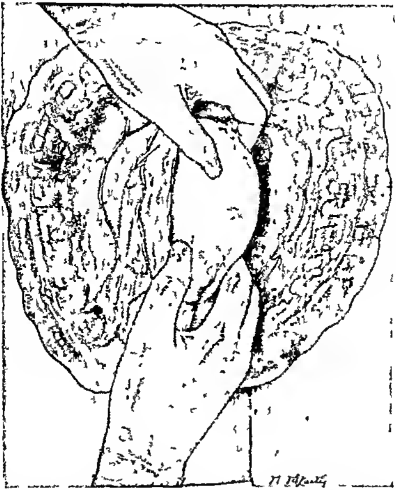


Fig 363 —Posterior gastro enterostomy The transverse colon has been turned up the meso colon incised and a portion of the stomach withdrawn

tension about 3–4 inches should be left The assistant, holding the handles of the clamps approximates the two, but, before bringing them together, a layer of gauze, 12 in by 2 in, is laid between and behind them so as to prevent extravasation when the viscera are opened (Fig 364) The clamps with their contained portion of stomach and jejunum are brought together The omentum, transverse colon, and the rest of the stomach are now replaced in the abdominal cavity through the upper part of the incision and the clamps and their contents are shut off from the peritoneal cavity by placing two pads

under and around them A suture of No 0 catgut mounted on an eyeless needle is passed through the sero muscular coats of both viscera near the handles of the clamps and tied The short end is clamped a second suture is passed in a similar mannr near the points of the clamps and tied The short end is also clamped The needle of the second suture is now passed to and fro as a continuous suture through the sero muscular coats along the whole length of the

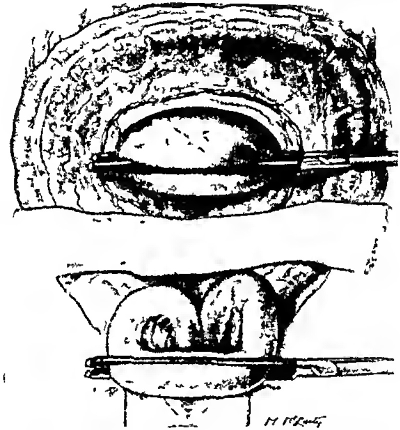
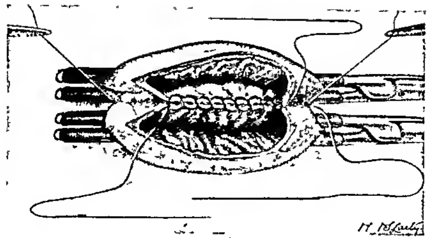


Fig 364 —Posterior gastro enterostomy The stomach and jejunum have been clamped and a roll of gauze placed between them.

approximated viscera and tied to the short end of the first suture It is then cut off

The stomach is then opened for a distance of 3 in by an incision parallel with the suture line and at a distance of a third of an inch from it This should always be done in two stages first the sero muscular and then the mucous coats Rarely is it necessary to remove any redundant mucosa for this must never be deficient at the suture line The jejunum is next opened by a similar incision The adjacent (posterior) edges of the openings in the stomach and jejunum are then united by a continuous through and through catgut suture (Fig 365 A) In this case the suture is mounted with eyeless needles



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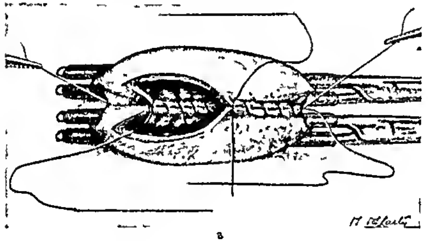
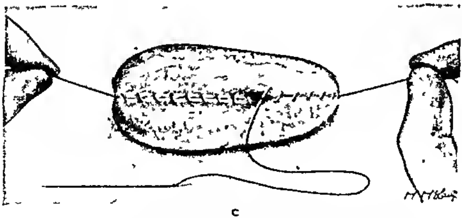


B



C

Fig 365 — Posterior gastro-enterostomy

A The posterior sero-muscular suture is completed and the through and through or hæmostatic suture commenced B The hæmostatic suture nearly completed C The clamps have been removed and the anterior sero-muscular suture is being completed

at either end and is best commenced near the centre. One needle is passed through all coats until one half the catgut has been passed, the two ends, each with a needle, are tied; one is then passed to and fro through all coats until the end near the handles of the clamps is reached. It then turns the corner and unites about a third of the length of the anterior edges, when it is tied. (Fig. 365, B.) *The suture* must be drawn sufficiently tightly to be hæmostatic. The other half

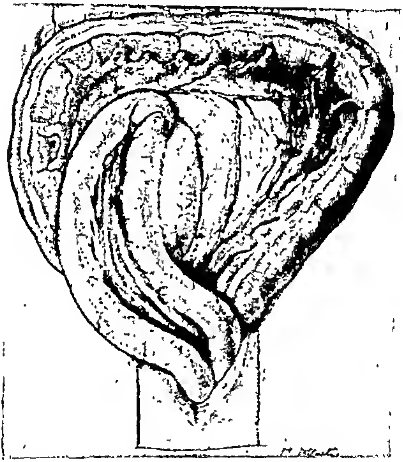


Fig. 366.—Posterior gastro-enterostomy. Anastomosis completed and the edges of the opening in the meso-colon sutured to the stomach.

of the suture is passed towards the points of the clamps, round this corner to unite the anterior margins until it meets the tied ends of the first suture when it is also tied. It does not matter if a little of the mucosa protrudes between the stitches. The clamps are now removed, and the suture line examined for bleeding points, which can be controlled if necessary by an occasional mattress suture. The sero-muscular suture is then resumed (Fig. 365, C) and the inner suture line buried by a continuous stitch which is finished off by knotting with the original end.

Some surgeons advocate three layers of sutures, the first being sero-muscular the second through the divided sero muscular layers and the third through the mucosa Since the chief function of the suture passing through all three coats is hæmostatic the use of the

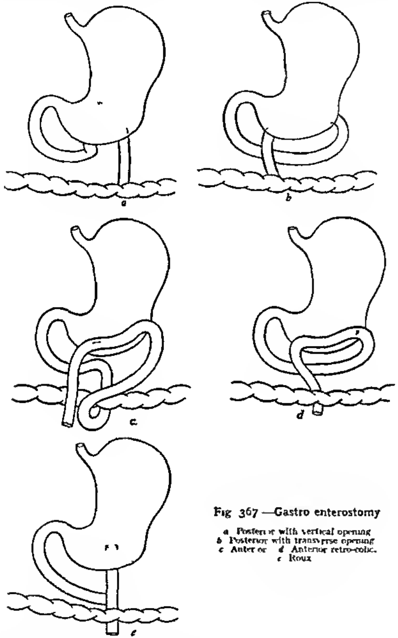


Fig 367 —Gastro enterostomy

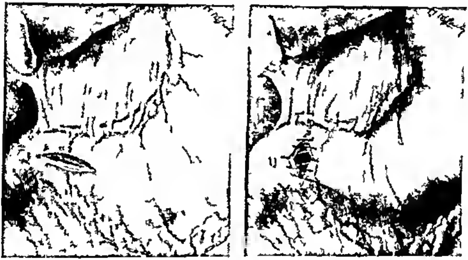
a Posterior with vertical opening
b Posterior with transverse opening
c Anterior d Anterior retro-colic.
e Roux

three suture method in my opinion is unsatisfactory as it defeats this function and is more likely to be followed by hæmorrhage

The gauze and the two protecting pads are removed and the opening in the transverse mesocolon is sutured to the stomach by three or four interrupted sutures so as to prevent postoperative hernia

(Fig 366) If the opening is stitched to the jejunum there is especially in fat patients a risk of obstruction by subsequent contraction After replacing the stomach in the abdomen any other abnormalities that have been found are corrected Some surgeons remove the appendix as a routine measure but as this means a prolongation of the operation and often an increase in the length of the incision it is better to do it only if the appendix contains concretions or is in any other way abnormal

If the mesocolon be short scarred or greatly thickened from the presence of fat or if the stomach be small and high up a posterior gastro enterostomy may be impossible or unwise The same may be true if the operation is being performed as a palliative measure for carcinoma which widely involves the posterior wall An anterior anastomosis is then performed A loop of jejunum is brought round



A B

Fig 368 —Pyloroplasty

A Longitudinal incision through pyloric sphincter B Transverse suture of opening

the transverse colon and clamped the loop should be sufficiently long just to pass round the colon without constricting it but must not hang as a free loop Its proximal limb will usually be 6–8 in in length The anastomosis in this case lies along the greater curvature with the afferent loop nearer the cardiac end and is not vertical (Fig 367 c) In cases where the stomach was adherent to the posterior wall but the mesocolon was of sufficient length Sherren advocated that the loop be brought through the mesocolon and gastro-colic omentum and united to the anterior wall of the stomach (anterior retro colic) (Fig 367 d) The clamps should be loosened before the anterior walls are sutured as all the big vessels enter the posterior walls and are divided when the opening is made When combined with wedge resection of an ulcer of the lesser curvature of the stomach a posterior anastomosis is performed but in this case it also runs along the greater curvature

with the afferent loop near the cardia and thus lies below the line of suture of the wound of incision (Fig 367, *b*) The Roux operation should never be performed as it diverts the alkaline secretions below the anastomosis

Pyloroplasty and Gastro-duodenostomy

These operations are widely performed by many surgeons but have not become very popular in this country

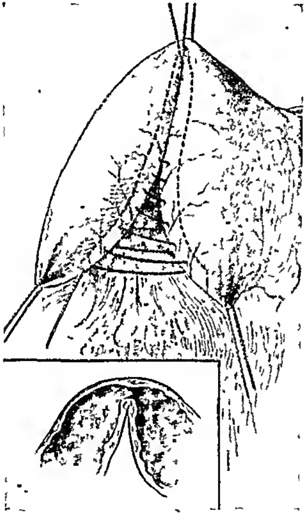


Fig. 369 —Finney's operation . approximating stomach to mobilized duodenum

Pyloroplasty.—The simplest of these operations is that known as the Heincke-Mikulicz operation or, in this country, as Allingham's operation A longitudinal incision about 1½ in long is made in the anterior wall of the pyloric canal and first part of the duodenum (Fig. 368, A) The incision should lie midway between the greater and

lesser curvatures and all coats are divided The walls of this longitudinal opening are pulled apart and the opening sutured transversely (Fig 368 B) It is useful in the few cases of definite stenosis where there is no evidence of active ulceration Such cases are the rare examples of apparent persistence of congenital stenosis to adult life

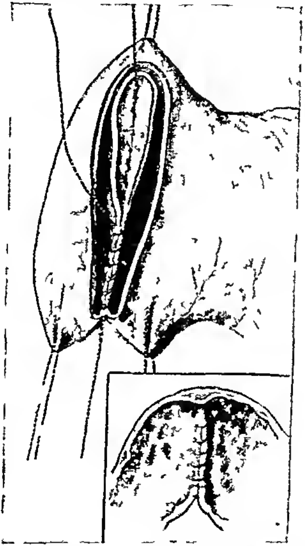


Fig 370 —Finney s operation, modified posterior all-coats suture

and possibly a few instances of scarring where an ulcer has healed In the rare conditions in which this operation is possible the results have been remarkably successful

Gastro duodenostomy —In this operation either the pyloric canal is much widened or a new communication is made between the stomach and duodenum. In the operations of Jaboulay and Kocher, and later

that advocated by Balfour a direct communication was made between the dilated stomach and the duodenum below the stenosed pylorus but the operation which has been most in vogue is that of Finney who has published a large number of successful results He claims that it can be easily and rapidly performed and allows of direct access to and excision of ulcers on the anterior wall and of some on the posterior wall and of direct control of any bleeding point He states that the pylorus must be freed from adhesions and the duodenum freely mobilized In his description the duodenum and stomach are united by mattress sutures of silk but in this country continuous sutures of catgut would be used as in any other union (Fig 369)

Balfour has modified this operation by excising the anterior half of the pyloric muscle with any ulcers on the anterior or lateral walls and cauterizing or excising ulcers on the posterior wall The pyloric outlet is then reconstructed usually by suturing the large opening transversely so as to leave a free passage between the stomach and duodenum He has obtained very satisfactory results by this method and has found it especially useful in cases of ulcer with hæmorrhage My own experience has been that these methods offer but little advantage over posterior gastro enterostomy and therefore I have employed them but

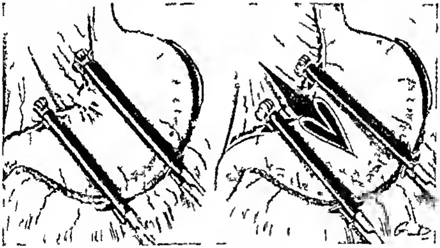


Fig 371 Excision of gastric ulcer Left application of clamps right ulcer and surrounding tissue excised

rarely If the ulcer be widely embedded by the silk mattress suture hæmorrhage can nearly always be well controlled and the gastro-enterostomy in my hands has proved the safer operation while the risk of local recurrence after these operations appears to be considerably greater than that of gastro jejunal ulceration after gastro-enterostomy

Excision and Gastro Enterostomy

Excision of an ulcer of the lesser curvature alone has proved unreliable about 50 per cent of the cases recurring but when combined with gastro-enterostomy the results are very satisfactory As with duodenal ulcers the lesion must be made manifest The transverse

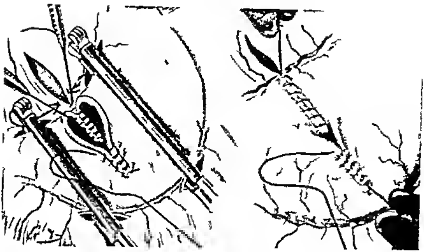


Fig 372—Excision of gastric ulcer Left, insertion of first row of sutures right, insertion of last row of sutures

colon and stomach are withdrawn from the abdomen and placed on the towels on the abdominal wall A free opening is made in the gastro-colic omentum and the ulcer explored posteriorly If very adherent over a large area to the pancreas a partial gastrectomy will probably be the operation of choice If the adhesions are smaller they are divided and the stomach freed The arterial arcade on the lesser curvature is then ligatured and divided with catgut or silk sutures ½ in proximal and distal to the ulcer Clamps are now passed across the stomach proximal and distal to the ulcer (Fig 371) The posterior blade of each is passed through the opening already made in the gastro colic omentum and emerges through the lesser omentum where the arteries were tied A gauze pad is passed along the same path behind the stomach A wedge-shaped portion of the stomach with its base at the lesser curve containing the ulcer and passing well free of its margins is now excised (Fig 371) The posterior margins are held up and their serous surfaces united by a continuous sero muscular suture of catgut commencing at the apex of the V The union of the posterior layers is completed by a continuous hæmostatic suture passing through all layers and also commencing at the apex The anterior layers in a like manner are united by two layers of sutures (Fig 372) The operation is completed by temporarily occluding the pylorus by inserting a running mattress suture of silk and performing a posterior gastro-enterostomy This latter step is done in the usual way but the opening is made to

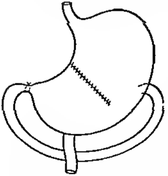


Fig 373—Completed operation of excision with gastro enterostomy

pass along the greater curvature below the suture line of the excision (Fig 373) If possible the opening should be so placed that one half of it lies proximal and one half distal to the line of excision

Cautery excision will be found most useful for small ulcers high up on the posterior surface where a wedge resection would be technically difficult An opening is made in the gastro colic omentum and any adhesions between the ulcer and the pancreas are divided The

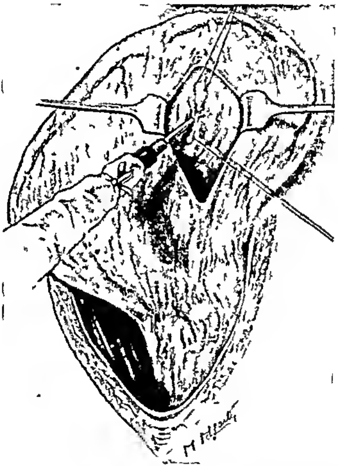


Fig 374 —Cautery excision of ulcer high up on posterior surface of stomach

stomach is now turned upwards so that the ulcer is exposed through the retracted edges of the gastro-colic omentum A fixation stitch is passed through the sero muscular walls of the stomach between the lesser curve and the ulcer and by traction upon this the posterior wall of the stomach and the ulcer are pulled away from the anterior wall which otherwise might be injured by the cautery The Pacquelin cautery is now passed through the base of the ulcer into the cavity of the stomach and the edges of the ulcer are completely burnt away (Fig 374) The resulting opening is sutured by two layers of catgut

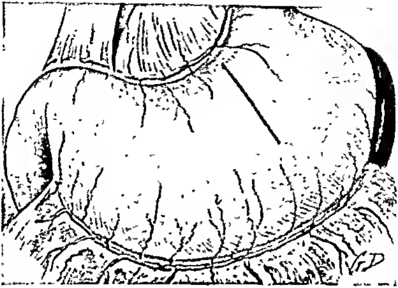


Fig. 375.—Transgastric resection: incision.

suture which usually have to be passed on a curved needle, and the operation is completed by occlusion of the pylorus by the mattress suture and the performance of a posterior gastro-enterostomy as for the wedge resection.

Transgastric resection will be found useful in a few exceptional cases where the ulcer is on the posterior surface of the stomach and is adherent to the pancreas. The stomach, which has been emptied by a stomach

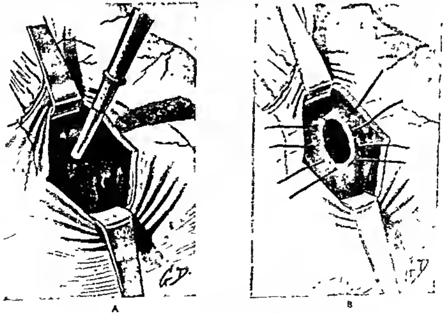


Fig. 376.—Trans-gastric resection.
A Application of cautery B Suturing from within the stomach.

tube, is opened by an incision through its anterior wall (Fig 375) This should pass at right angles to the two curvatures Its edges are retracted and the ulcer is freely excised either with the scalpel or cautery (Figs 374 376, A) The resulting opening in the posterior wall is sutured with through and through sutures from within (Fig 376, B) The anterior opening in the stomach is now closed, the viscus turned up and the posterior wound reinforced by a sero muscular suture of catgut The operation is completed with the usual temporary occlusion of the pylorus and a gastro enterostomy

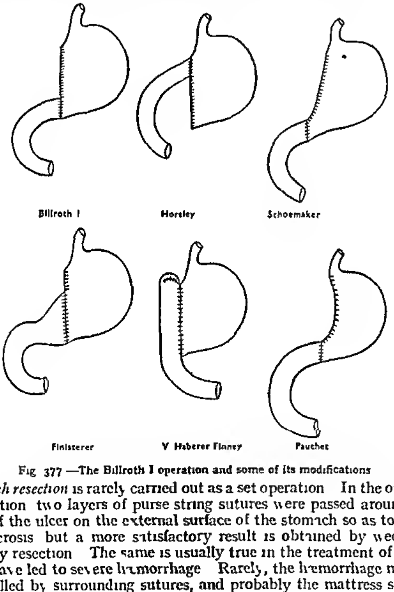


Fig 377 —The Billroth I operation and some of its modifications

Stitch resection is rarely carried out as a set operation In the original suggestion two layers of purse string sutures were passed around the area of the ulcer on the external surface of the stomach so as to cause its necrosis but a more satisfactory result is obtained by wedge or cautery resection The same is usually true in the treatment of ulcers that have led to severe hæmorrhage Rarely, the hæmorrhage may be controlled by surrounding sutures, and probably the mattress sutures used to close a perforation on the anterior wall of the stomach act in the same way If inserted to control hæmorrhage and often if used

to close a perforation this step should be combined with occlusion of the pylorus and gastro-enterostomy

Partial Gastrectomy

Many methods of partial gastrectomy have been performed some of which have become obsolete They differ mainly in the method by which the subsequent anastomoses are performed and are represented diagrammatically in Fig 377 The two most commonly performed to-day are (*a*) Some form of the Billroth I where the stomach is united to the open end of the duodenum and (*b*) some variety of the Polya

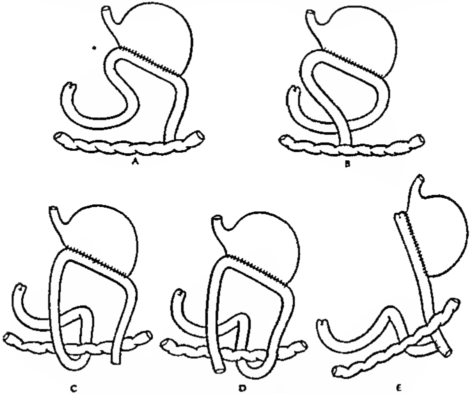


Fig 378 —The Polya operation and some of its modifications

A Polya iso-peristaltic B Posterior retro-peristaltic as used for gastro-jejunal ulceration with short afferent loop C Balfour anterior iso-peristaltic D Moynihan anterior retro-peristaltic E Roux

operation where the cardiac end of the stomach is implanted into the side of the jejunum (Fig 378) Where possible it is my own custom to choose the Billroth I method as this approximates more to the normal anatomy and to use the Polya method where the duodenum is stenosed or widely ulcerated or in rare cases where approximation is difficult

The Billroth I operation —The abdomen having been explored and the lesion made manifest the great omentum and transverse colon are drawn out of the wound Some surgeons remove the great omentum with the stomach as a routine In this case it is lifted up and the line of cleavage between it and the transverse colon made manifest with a

few touches of the scalpel It is then usually quite easily freed from the upper surface of the mesocolon The avascular layer forming the posterior layer of the lesser sac is opened and the omentum divided between ligatures at the pyloric end of the stomach and above at the line of gastric section These ligatures control the right gastro epiploic artery at the pyloric end and the left gastro-epiploic artery, at the cardiac end My own preference is to preserve the omentum for its

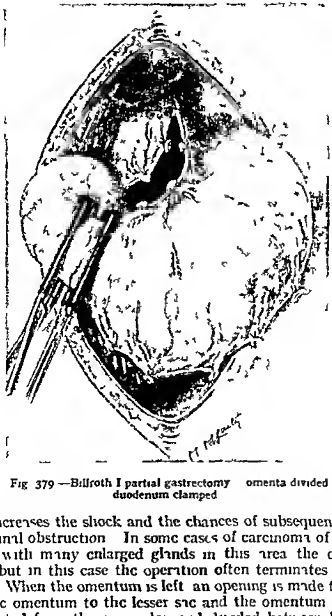


Fig 379 —Billroth I partial gastrectomy omenta divided duodenum clamped

removal increases the shock and the chances of subsequent adhesions and intestinal obstruction In some cases of carcinoma of the greater curvature with many enlarged glands in this area the omentum is removed but in this case the operation often terminates as a Polya resection When the omentum is left an opening is made through the gastro colic omentum to the lesser sac and the omentum is lifted up and separated from the mesocolon and divided between ligatures as far down as the duodenum thus dividing the right gastro-epiploic artery A finger is passed up behind the pylorus and through the

lesser omentum and the portion of lesser omentum lying between the finger and the duodenum, which contains the pyloric artery is ligatured and divided By this means the important structures in the gastro-hepatic omentum are pushed to the right out of harm's way The duodenum is thus freed and is divided between two clamps (Fig 379) If the Finsterer modification is adopted, the division is made on the gastric side of the pylorus Both ends are now covered with an abdominal pad The stomach is drawn down, a finger is inserted

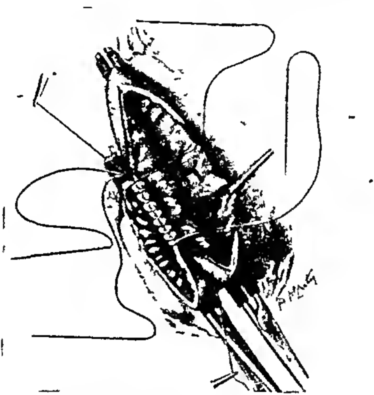


Fig 380 —Billroth I partial gastrectomy
The requisite portion of stomach has been removed, the posterior sero-muscular suture completed, and the hæmostatic suture commenced.

behind the upper part of the lesser omentum and the coronary artery is defined and divided between ligatures high up on the lesser curve, the ligature on the upper end being left long The stomach is thereby mobilized the remaining portion of the gastro-colic omentum is now divided up to the line of section of the stomach, thus controlling the left gastro-epiploic artery The stomach is lifted up and clamped proximal to the proposed line of section and removed about ½ in distal to this In the Schœmaker operation a special clamp is used so that there are two lines of section meeting at an angle; the upper is closed and the lower alone used for the anastomosis In the Billroth I method

the clamps are approximated and an end to end union is performed, the stitches being best inserted in the following manner a sero muscular suture is passed through the lower borders of the duodenum and the greater curvature of the stomach and a second similar suture is passed through the upper border of the duodenum and a corresponding point on the posterior wall of the stomach Both short ends are clamped and the needle of the first suture is again picked up, the posterior walls of the duodenum and stomach being united by a running sero muscular suture (Fig 380) On reaching the upper

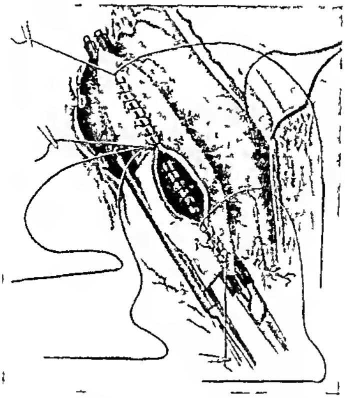


Fig 381 —Billroth I partial gastrectomy
The hæmostatic suture is nearly completed

border of the duodenum it is securely tied to the short end of the second suture A double needled suture of catgut is now passed through all coats of the posterior walls about the middle for half its distance and tied One end passes upwards through all coats of the posterior walls until the upper limit of the duodenum is reached, it then leaves the duodenum and passes through anterior and posterior walls of the stomach so as to close that portion of the stomach above the anastomosis with the duodenum At the level of the lesser curve it is tied (Fig 381) The lower needle passes downwards to unite the posterior walls in the lower part, on reaching the greater curvature it turns round the angle to unite the anterior walls and on reaching the

upper border of the duodenum is tied The clamps are now removed and if there is no bleeding the long end of the first sero-muscular stitch is used to embed the united walls of the stomach above the anastomosis being tied at the lesser curve It is then tied to the ligature left on the coronary artery, thus covering the raw area of the lesser curvature The long end of the second sero-muscular stitch passes downwards to embed the united anterior walls of the stomach and duodenum, and when it reaches the greater curvature is tied to the short end of the first sero muscular stitch (Fig. 382) By this method only two sero-

Fig 382 —Billroth I partial gastrectomy
Clamps removed and anterior sero muscular suture being completed

muscular stitches are used and one double-needled stitch, and the junctions being closed with the continuous stitch, are all firm

In the Haberer-Finney method the cut end of the duodenum is closed and embedded, and the cut end of the stomach is *implanted* into the side of the duodenum below the closed end It may be found useful when there is a chronic ulcer of the lesser curvature combined with a second ulcer of the first part of the duodenum

For ulcers situated high up on the lesser curvature Pauchet's modification will be found very useful The preliminary steps are the same but, after the stomach has been mobilized and the duodenum divided the stomach is shut off from the abdominal cavity by pads and is clamped just *below* the ulcer, and that portion of the stomach distal to

the clamp is removed. (Fig. 383.) Several Spencer Wells forceps are now applied to the cut edges, the stump of the stomach is held up, the clamp removed, and the cardiac end emptied with a suction-pump. The lesser curvature, with the ulcer, is now excised, and these two

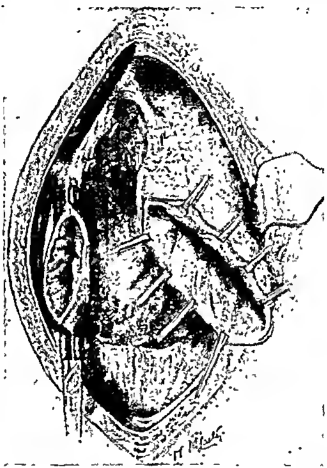


Fig. 383.—Pauchet's operation. The stomach below the ulcer has been removed, the cardiac stump is held up by forceps and the line of incision of the lesser curvature with the ulcer is indicated.

edges sutured with two layers of sutures. (Fig. 384.) If the incision encroaches on the œsophagus the passage of a large œsophageal tube will facilitate the subsequent suturing. The remaining opening of the stomach below this line of suture is either united to the duodenum in the usual way or the operation is completed by the Polya method.

In the Billroth II procedure the duodenal and gastric stumps were both closed and a gastro-enterostomy was performed between a loop of jejunum and the cardiac portion of the stomach, the anastomosis being made either ante- or retro-colic. Personally I have given up this

operation for either the Billroth I operation or some variety of the Polya method have in my hands been more satisfactory

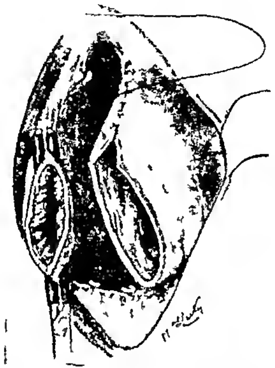


Fig 384 —Pauchet s operation Suture of the lesser curvature When this is finished the operation may be completed by either the Billroth I or the Polya methods

The Polya operation—In the operations coming under this group the cut end of the stomach is implanted into the side of a loop of jejunum They showed a great advance upon the Billroth II operation which was the accepted operation at the time of their introduction in that as the stump of the stomach did not have to be closed a larger portion could be removed and the danger in the Billroth II method (that the opening for the gastro-enterostomy might by dividing vessels devitalize the tissue at the site of the closed stump) was abolished

In the Polya method the first step consists of removing the great omentum or dividing the gastro-colic omentum in a precisely similar manner to that employed in the Billroth I method The first part of the duodenum is freed by division of the pyloric artery in a similar manner This portion of the duodenum is now divided between clamps and the distal end closed Many surgeons use a crushing clamp and embed the cut end around the clamp I prefer never to use crushing clamps as these will temporarily close all vessels and thus give a false sense of security It is my custom to use a light clamp with blades

protected with rubber and to divide the duodenum sufficiently far proximal to these to allow the passage of a continuous through and through catgut suture the clamp is now slipped off and if any small vessels bleed they are picked up and tied The same catgut suture is now used in the reverse direction as an embedding suture passing only through the sero muscular coats and is tied at the lower margin with the original short end thus finally embedding the stump This is again covered by a continuous silk suture which picks up in turn the edge of the gastro-colic omentum the lesser sac over the head of the

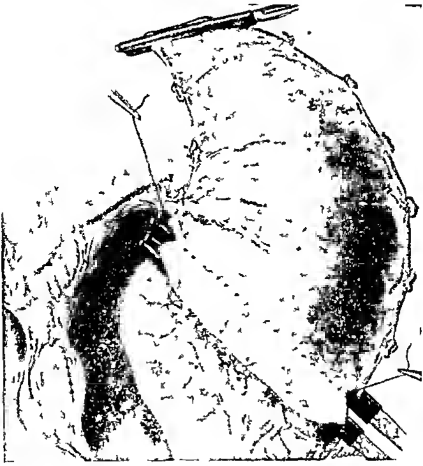


Fig 385 —Polya partial gastrectomy Duodenum divided and closed Sero muscular suture completed

pancreas the lesser omentum and the outer wall of the duodenum, so that when this is tied the stump is securely embedded and covered in peritoneum The proximal end still clamped is covered with an abdominal pad to prevent infection The stomach is drawn down the coronary artery divided between ligatures and the great omentum divided up to the proposed line of section as in the Billroth I operation An opening is now made in the mesocolon and a loop of jejunum is

drawn up through it and clamped at the proposed site of anastomosis the afferent loop passing to the lesser curvature It was formerly the custom to make this opening as near the flexure as possible this caused tension on the afferent loop and is the probable reason why some surgeons found the method unsatisfactory The afferent loop should be long enough to reach the lesser curvature with no tension It will generally be four to five inches in length The selected loop is lightly clamped in rubber-covered clamps placed obliquely with the efferent loop near the handles the included portion being sufficiently long to allow an opening equal in length to the cut end of the stomach The stomach is turned over to the left and also clamped with light rubber-covered clamps passing from the greater to the lesser curvature The clamps on the jejunum are brought up into alignment with those on the stomach and the two viscera are united by a sero muscular continuous suture of catgut passed as in performing gastro enterostomy (Fig 885) The stomach is again clamped to prevent leakage and opened between the clamps The jejunum is also opened The posterior walls are united by a continuous through and through catgut suture the anterior wall of the stomach is then divided the diseased portion removed and the two anterior walls of the stomach and duodenum are united All these sutures are passed in a similar manner to that employed in performing a gastro-enterostomy (Fig 886) By dividing the stomach in this way and suturing the posterior walls before the anterior stomach wall is divided the stump of the stomach is prevented from retracting and infection is minimized

Some surgeons partly close the end of the stomach and only use the lower portion for the anastomosis This is unnecessary The rate of emptying is controlled by the size of the efferent loop which is always smaller than the anastomotic opening and it therefore makes no difference if the opening is two or six inches in length

When the anastomosis is completed the transverse colon is turned up the stump of the stomach is drawn through it and the edges of the mesocolon are fixed to the stomach just above the anastomosis with two or three catgut sutures

In the Balfour and Moynihan modifications a loop of jejunum is brought up in front of the transverse colon the afferent loop in the former being united to the lesser curvature and in the latter to the greater curvature These two methods have the advantage that the mesocolon cannot constrict the efferent loop I have felt however that this loop is more likely to be obstructed by being kinked over the transverse colon and of late have more frequently reverted to the original Polya method

In the Roux method (Fig 877 E) the jejunum is divided completely across the stump of the stomach is implanted into the side of the distal end and the cut proximal end is implanted into the side of the distal end below the gastric anastomosis This operation has nothing to recommend it It should never be employed for peptic ulcers as the alkaline secretions of the jejunum enter below the gastric anastomosis

and hence gastro-jejunal ulceration is very common The same is true of a lateral anastomosis between the afferent and efferent loops, which is advocated from time to time but is almost certain to be followed by gastro-jejunal ulceration In fact these operations are types of the methods used by Mann and Williams to produce experimental ulcers in animals

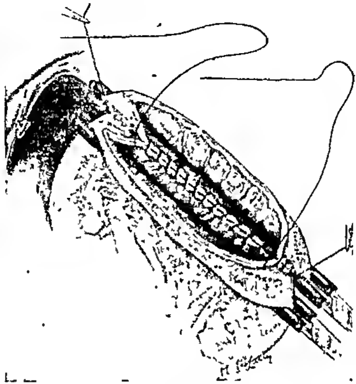


Fig 386.—Polya partial gastrectomy
The hæmostatic suture is nearly completed

Postoperative treatment.—Shock does not generally follow gastro-jejunostomy, though it may be present after major resections of the stomach It is well to administer per rectum, in such cases, a pint of tap-water, in which is dissolved 1 oz of glucose, when the patient returns to bed Patients are put in Fowler's position as soon as they have come round after the anæsthetic, and retain this position throughout. It makes breathing easier and lessens the tendency to vomiting.

The routine treatment for the first week is as follows —

Small sips of water only are allowed by the mouth for twenty-four hours or for forty-eight hours after perforation or resection operations; on the second day, diluted milk, lemonade and weak tea are also allowed in sips On the third day the quantities are increased until one to two ounces of fluid are taken at a time By the fifth day, a lightly boiled egg, Benger's food, jelly, custard and junket are allowed.

The diet is slowly increased fish eggs bread and butter and toast being given by the seventh day a little chicken or sweetbread may be added at the end of ten days For two months small meals at frequent intervals should be taken and alkalis should be administered until the end of three months after operation

As with all abdominal operations the bowels should be given complete rest One of the surgeon s greatest difficulties is to prevent the early administration of aperients which will probably produce ileus An enema should be given on the third day and if necessary repeated on the fourth Only after an action is obtained should a mild aperient be given

In the early stages pain may be combated by morphia

After operation no heavy muscular work or exercise should be allowed for at least three months

Postoperative complications—These may be divided into immediate and late The former consist of hæmorrhage acute dilatation of the stomach and regurgitant vomiting the latter of gastro jejunal (peptic) ulcer and obstruction of or around the anastomosis or intussusception of the anastomosis into the stomach

Hæmorrhage is due to failure to control all the bleeding points at the stoma by the continuous through and through (innermost) suture To prevent this complication many methods of applying the suture have been suggested the usual one being some form of mattress suture The more complicated this suture is and the more knots it contains the more risk there is of a gastro jejunal ulcer A simple running suture if properly applied is sufficient but the greatest care must be taken that each stitch falls exactly perpendicular to the line of suture and is pulled tight and yet not too tight The bites of the stitch should be not more than $\frac{1}{8}$ in apart It is the application of this suture which determines success or failure

If hæmorrhage persists there is no method which can be relied upon to control it short of re opening the abdomen Fortunately in the great majority of cases the hæmorrhage ceases spontaneously Of the drugs used adrenaline (1 drachm of 1 in 1 000 in an equal quantity of water repeated hourly for six doses nothing else being given by mouth during this period) is often efficacious but no direct application of a styptic can be of value if the stomach is full of clot so the stomach must be washed out as a first step Probably the best treatment is to relieve the patient s anxiety and restlessness by a hypodermic injection of morphia which is often followed by cessation of the bleeding If however the bleeding continues so that life is threatened the abdomen must be re-opened an incision made in the anterior wall of the stomach the stoma exposed and the bleeding point secured with a catgut stitch

Acute dilatation of the stomach—This complication which may follow any operation under a general anæsthetic and has been reported

in cases of grave illness e g typhoid fever may even occur after the formation of a free gastro enterostomy opening

During the course of the operation or within the first twelve hours afterwards the stomach becomes suddenly dilated generally with gas only sometimes with gas and a greyish or dirty brown fluid The patient becomes seriously ill as if poisoned the heart s action is embarrassed by the enormously dilated stomach and death will ensue if successful treatment is not adopted The cause is still uncertain The first serious attempt to explain it was by Allbrecht his theory that it was due to occlusion of the duodenum by the superior mesenteric artery as a result of the pull of the small intestines had many adherents and was favoured by the success of postural treatment as suggested by Schnitzler* but as the condition can occur in spite of the presence of the wide stoma of a gastro enterostomy and has often been noted without any duodenal dilatation and as the method of treatment by gastric lavage (which could have no effect on the pull of the small intestines) is successful in the great majority of cases Allbrecht s theory is not widely held at the present day It is now generally believed that the condition is one of paralysis of the gastric wall in every way analogous with ileus paralyticus with which indeed it may be associated

Treatment consists in passing the stomach tube evacuating the stomach contents and washing out with bicarbonate of soda solution or saline Relief can sometimes be obtained by turning the patient on his face but lavage is simple safe and effectual As a rule the passage of the tube gives exit to a quantity of gas and fluid contents with dramatic result

Regurgitant vomiting is the result of an obstruction high up in the jejunum and may be due to gross errors in the operative technique such as the formation of too small a junction especially if combined with a long afferent loop so that kinking occurs axial rotation and obstruction of the efferent loop too high an opening or union of the anterior and posterior walls of the opening Such errors are rare to day the few cases that are seen being usually due to constriction of the efferent loop by the mesocolon which in the first few days has become œdematous or later fibrous The complication can generally be avoided by suturing the edges of the opening not to the line of the anastomosis but to the stomach wall about ½ in away from the anastomosis With a fat laden mesocolon the danger is increased owing to the width of the cut edge If appearing within a few days of operation the symptoms will often disappear with lavage but if they appear about the 10th day they will probably be due to fibrosis and a further operation will probably be required As a rule when the abdomen is re opened and the parts are examined the cause of the condition is not clear except that there is some obstruction about the site of the gastro-enterostomy The best way to deal with the trouble is to make an entero anastomosis between the proximal and

* W n. klin Rundschau 1895 ix. 579 81

distal loops of the gastro enterostomy by the Finney method This should be carried out by direct suture an opening of about an inch and a half will suffice A lateral union below the anastomosis should never be used as it increases the subsequent liability to marginal ulceration

Late complications **Gastro jejunal ulcer**—This ulcer occurs at or near the suture line and may give rise to symptoms very shortly after the operation Many believe that no symptoms may arise until years after but prolonged experience in a follow up department has convinced me that these patients very rarely make the complete recovery expected at the operation While it primarily depends on a high acidity there is some evidence that its frequency is increased by faulty technique In many of these ulcers a non absorbable suture has been found hanging and it seems an obvious precaution to use an absorbable suture for this layer Failure of mucosal apposition at the line of junction or hæmorrhage beneath the mucosa seem to play a part faults which can only be avoided by meticulous care in suturing The treatment is considered on p 781

Obstruction of or around the anastomosis—The most common cause of such obstruction is stenosis following a gastro-jejunal ulcer In rare cases late obstruction may be due to a herniated loop of intestine passing beneath the anastomosis or through the opening of the meso colon Both these complications should be prevented by correct operative technique More rarely still a retrograde intussusception of the intestine may occur through the stoma into the stomach Such a condition will give rise to symptoms of acute obstruction high up and will necessitate prompt operative interference

Complications of Peptic Ulceration

Perforation—Perforation of a peptic ulcer is a complication which is almost inevitably fatal unless an operation be performed The results depend directly upon the interval between the perforation and the operation Therefore the diagnosis having been made steps must be taken for operation at the earliest possible moment and in no case must it be deferred until peritonitis has occurred

Nothing may be given by mouth no attempt at stomach lavage is permissible but a sufficient dose—at least gr $\frac{1}{4}$—of morphia with atropine gr $\frac{1}{100}$ or omnopon gr $\frac{1}{3}$ should be administered as soon as an operation has been decided upon especially if the patient has to be transported to hospital or nursing home The Fowler position should be adopted or at least the head of the bed should be raised and this position should be maintained until the patient is on the operating table The skin of the abdomen should not be prepared until he is on the table

Operative technique—Open ether or gas and oxygen will usually be found the most satisfactory anæsthetic A small suprapubic incision should be made The diagnosis is confirmed from the nature of the exudate and a tube is inserted down to the bottom of the pelvis to

allow the fluid to drain away during the operation An upper right paramedian incision is now made The perforation is as a rule easily found on the anterior surface of the stomach or duodenum If not seen in this position the lesser sac must be opened by an incision in the gastro-colic omentum and search made for the perforation of a posterior ulcer The opening having been located it must be closed by mattress sutures of catgut passed sufficiently far from the opening to enter healthy tissue When these are tied the whole ulcer and perforation are embedded (Fig 387) If the suture be passed sufficiently far from the perforation to enter healthy tissue no other measure is ever necessary for a simple ulcer

Fig 387 —Method of suturing a perforated gastric ulcer

The next question that will arise is whether a gastro-enterostomy should be performed In large part this will depend upon the experience of the surgeon and the time he is likely to occupy in carrying out this step The majority of these ulcers are chronic and if simple suture alone is performed a subsequent operation may be necessary In my own series 50 cases have been referred to me for gastro enterostomy after simple suture elsewhere The performance of the anastomosis at the time not only increases the likelihood of a permanent cure but lessens the probability of gastric distension during convalescence If the ulcer be near the pylorus the embedding suture may cause stenosis On the other hand the first duty of the surgeon is to save the patient s life and a gastro-enterostomy even in the hands of the most skilful will occupy at least another ten minutes and the operative manipulations will increase the tendency to spread

infection For these reasons many surgeons advise only a simple suture in every case The strongest advocate of immediate gastro enterostomy was Deaver who considered it essential and published* a list of 56 cases with 2 deaths and 54 consecutive recoveries

My own views are that if the patient is extremely ill the perforation has been of long standing or there is a great deal of extravasation simple suture should alone be performed but it is very probable that subsequent operative measures will be required for the treatment of a persistent chronic ulcer If the condition of the patient is relatively good the gastro-enterostomy should be performed immediately after suture of the perforation But in any event at the conclusion of the operation the tube which has been inserted through the suprapubic incision in the pelvis should always be left in place and if there is but little discharge may be removed in two days If there has been much exudate a second tube may be required down to the perforation but this is as a rule unnecessary No other steps should be taken to cleanse the peritoneum The wounds are closed in the usual way but two or three tension sutures of through and through silkworm gut are used in the paramedian incision

Of late many surgeons have been advocating excision and even partial gastrectomy in early cases and several series of very successful results have been published In this country it is usually felt that such methods are too severe for so grave an emergency

The patient should always be nursed in the Fowler s position

After the operation sips of water alone should be given by mouth for twenty four hours If the patient is dehydrated rectal glucose 1 ounce and water 1 pint should be administered In very severe cases intravenous saline may be required After twenty four hours the ordinary treatment for all gastric lesions may be gradually in stituted the patient being kept in Fowler s position for ten days

Complications —The most frequent complication is subdiaphrag matic abscess which may occur in any of the six subdiaphragmatic spaces but generally arises in the left or right anterior intraperitoneal space

Shock peritonitis and ileus are all more common than with other gastric lesions owing to the infection probably for the same reason pulmonary complications are not infrequent

Results —In perforated gastric or duodenal ulcer the result depends mainly on the delay between perforation and operation The mor tality has decreased considerably since Mayo Robson published his 133 cases with a death rate of 28 5 per cent for cases operated upon in the first twelve hours 63 6 per cent for those in the second twelve hours and 87 5 per cent for those in the third twelve hours In my own series of 74 cases the total mortality was 29 7 per cent but in the 35 cases operated upon within twelve hours of the perforation it was only 8 5 per cent In 1931 Grey Turner published a remarkable

* Ann Surg Nov 19 9 lxx 528

series of 365 cases with an over all mortality of just over 15 per cent In 267 of the cases intervention took place within 12 hours and the mortality was 6 61 per cent (Murphy Oration) In a further series representing the work of four Newcastle surgeons which Grey Turner brought forward at a meeting of the Surgical Section of the Royal Society of Medicine in 1937 there were 450 cases operated upon within twelve hours with a mortality of 9 55 per cent and of these 247 were operated upon within six hours with a mortality of 4 4 per cent Hughes in 1930 reported a series of 101 cases nearly all treated by simple suture with a total mortality of just under 12 per cent The death rate as shown by the published statistics indicates little variation with the method used In Scotson s series * it was 13 per cent in 107 cases of simple suture and 8 3 per cent in 24 cases of gastro enterostomy In Semb s series of 166 cases † the total mortality was 15 7 per cent although nearly all were treated by suture and gastro enterostomy and he found that 75 per cent were permanently cured Judin of Moscow‡ has published a remarkable series of 418 cases with a total mortality of 12 8 per cent Of these 168 were treated by partial gastrectomy with a mortality of only 5 9 per cent but the time which elapsed between perforation and operation is not stated

There has been considerable discussion about the end results Some surgeons believe that after recovery from simple suture symptoms will not recur My own close follow up of cases does not confirm this statement Paterson says that 23 per cent of cases relapsed within a year Williams and Walsh in 1930 found that in a series of 98 cases over 50 per cent required subsequent operation As already men tioned 50 patients have been referred to me for further operation after simple suture for perforation performed elsewhere

Hæmorrhage —There is perhaps no complication of peptic ulceration in which it is so difficult to determine whether an operation should be performed If the patient be left the hæmorrhage may abate and the patient recover but on the other hand it may continue or be repeated and the patient die If the hæmorrhage has been at all severe the patient is always a bad surgical risk and the operation may prove fatal, but if the condition be left alone the danger of operation may be increased by further hæmorrhage Of recent years an acute controversy has taken place between those who believe in immediate operation for all cases and those who advocate that the patient be treated medically until the acute stage is over Here again statistics are of very little value for in those lists which are published to show the efficacy of medical treatment the majority of minor degrees of hæmorrhage are included whereas those who advocate immediate surgical interference have as a rule only come in contact with very severe examples among which there is a high mortality In this country figures have been published by Gordon Taylor strongly

* *Brit Med Journ.*, Oct 14 1933 ii, 690
† *Acta Chir Scand* , Sept. 1 1933 lxvi, 315
‡ *Surg Gyn and Obst*, Jan., 1937 lxiv 63

supporting the view that every case should be operated upon in the earlier stages but to this view the majority of physicians and surgeons are opposed

My own experience has been that recovery usually follows if the patients are kept absolutely quiet in bed with little or no food by mouth morphia being administered hypodermically and suprarenal extract orally My custom has been to reserve operative interference for those cases where a hæmorrhage has been repeated in spite of medical treatment and where the patient is manifestly going downhill In such instances a blood transfusion should be given immediately before the operation and a donor should be at hand so that this can be repeated immediately after the operation For hæmorrhage in cases of acute erosion nearly all physicians and surgeons are averse from any operative treatment for it is manifest that since the erosions are often multiple and give rise to no thickening of the stomach wall it may be impossible at operation to determine the site of origin of the hæmorrhage and that any operation undertaken must be indirect Nevertheless I am of the opinion that certain cases may be saved by occlusion of the pylorus and gastro-enterostomy Here again an operation should only be undertaken if the hæmorrhage be repeated and if it be the firm opinion of a competent physician that the condition would be fatal if left It must be clearly understood however that the diagnosis between hæmorrhage of this type and that arising from chronic ulceration ought not to present any gross difficulties and no surgeon should operate upon one of these acute ulcers with the idea of finding a definite lesion and if he does not do so of closing the abdomen He should only operate if he is of the opinion that a gastro-enterostomy with temporary occlusion of the pylorus will control the loss of blood In these cases also the operation should be preceded by a blood transfusion

Operative technique—The abdomen should be opened by a right paramedian incision If the operation be for an acute erosion the pylorus should be immediately embedded with a running mattress suture and a posterior gastro-enterostomy performed In chronic ulceration the operative technique is more difficult It has been my experience that in the majority of cases of duodenal ulcer a running mattress suture of silk used as for temporary occlusion can be so placed that the anterior wall of the duodenum is folded up and firmly compressed upon the ulcer the lumen of the duodenum being entirely obliterated A posterior gastro-enterostomy is then performed There are however certain cases in which there is so much induration around the ulcer that more than half of the circumference of the wall is rigid and fixed and thus cannot be infolded In such cases many different procedures have been undertaken to control the hæmorrhage but any form of ligature of the gastro-duodenal artery is as a rule unsatisfactory I believe that the only certain treatment is to open the duodenum underpin the bleeding vessels and suture the ulcer crater together with interrupted catgut sutures In suturing the

anterior wall of the duodenum this should be embedded as far as possible so as to occlude the lumen, and a gastro-enterostomy should then be performed Some surgeons advocate partial gastrectomy or duodenectomy, but my own experience has been that such procedures are too extensive for patients who have had severe hæmorrhage

With a gastric ulcer there is equal difficulty Many have attempted to control the hæmorrhage by ligaturing the coronary arch of vessels or the large branches going to the site of the ulcer The anastomosis, however, is usually so complete that such methods will probably fail Opening the stomach and picking up the vessel in the base of the ulcer, with subsequent suture of the ulcer crater is probably the best treatment for very large and adherent ulcers where any more radical procedure would be fraught with considerable danger For the smaller or more mobile ulcers, my own custom has always been either to excise the ulcer or to perform a partial gastrectomy immediately proximal to it In fact, the procedures carried out in these cases have been almost identical with those for non bleeding ulcers These more radical forms of treatment are the only ones which hold out any hope of success, and it is because they are all severe and likely to add to the risk to life that my usual custom is to treat these cases medically until they are recovered from their hæmorrhage Every case, however, must be treated on its own merits and if it is felt that the patient has a good chance of recovery medical treatment should certainly be instituted If, however, medical treatment has failed and the hæmorrhage has been repeated, operation should be undertaken as offering the patient the only chance

Hour-glass Stomach

Hour glass stomach is a complication which is found with ulceration of the lesser curvature It is almost entirely limited to women, in my own series of 90 cases only one was a male In rather over 20 per cent of the cases it is associated with duodenal ulcer, and in nearly 50 per cent of the cases the patients have a general visceroptosis

Indications for operation.—The hour-glass constriction may only be of a mild degree and only evident on X-ray investigation In such cases the problem in no way differs from that of the treatment of lesser curve ulcer If, however, the isthmus is narrow, an operation will almost certainly be required, and this is especially true if there are clinical evidences of obstruction In such cases it used to be the custom to direct efforts to the cure of the obstruction, but it must always be remembered that the underlying factor is the presence of an ulcer and, although it may not at the time of the operation be manifestly active, any short circuit around the isthmus or plastic operation to overcome the narrowing is almost certain to be followed by a recrudescence of the ulcer, the same applies to gastro-enterostomy proximal to the ulcer

Operative technique.—The stomach having been exposed in the usual manner, the treatment of the isthmus and the ulcer will depend

upon the amount of narrowing The majority of surgeons perform a partial gastrectomy but in certain cases the isthmus may be situated high up in the stomach and thus necessitate the removal of a large portion in order to eradicate an ulcer which may be less than ½ in in diameter It is my own custom therefore if the isthmus is sufficiently wide to perform a wedge resection the limbs of the V running very obliquely so that when the opening is sutured the narrowing is entirely overcome The pylorus is then occluded with a running mattress silk suture and a posterior gastro enterostomy is performed lying in the isthmus below the line of resection and parallel with the greater curvature If possible it should be posterior but if a wider portion of the posterior wall has had to be excised it can equally well be made anterior This operation is less severe than a partial gastrectomy removes less of the healthy stomach and gives very satisfactory results In my own series 31 cases were treated by this method with two deaths and one recurrence after several years If the isthmus is so narrow that insufficient normal tissue can be left for the gastro enterostomy a partial gastrectomy must of necessity be performed It is an operation of greater severity for very often these patients are wasted and in poor condition In my own series 55 were treated by this method six died and one probably owing to the extent of the removal developed a profound anæmia after several years When the stomach is being resected the anastomosis can be completed by any of the methods which are most convenient If the duodenum is widely stenosed or approximation is difficult a Polya anastomosis should be performed but in the majority the Billroth I union is preferable for it has a slightly lower mortality and gives satisfactory end results

DUODENAL ILEUS

An acute dilatation of the duodenum may be found in postoperative conditions associated with acute dilatation of the stomach In fact as a general rule in such cases the whole of the intestinal tract is affected Apart from these a chronic dilatation and hypertrophy is sometimes seen Rarely the distension is enormous and may be regarded as similar in its ætiology to Hirschsprung s disease Such a condition is usually designated giant duodenum Of recent years the work of Wilkie has directed attention to a lesser degree of dilatation which he calls chronic duodenal ileus In this there is a dilatation of the duodenum often associated with discomfort and vomiting Wilkie has found this condition associated with duodenal ulcer or gall stones and believes that it is due to an obstruction at the line of crossing of the superior mesenteric artery In my own experience this condition has been less common and has generally been found in female subjects affected with visceroptosis My own view is that in the majority the condition is atonic and little or no benefit is likely to follow an anastomosis In some cases however the condition is definitely obstructive and is associated with hyper

trophy of the duodenal wall, in these cases alone is an operation likely to give relief Careful medical treatment should first of all be instituted and this more especially if the patient has visceroptosis and the symptoms are increased by exercise In such cases massage, rest and an abdominal belt may bring about relief If however, the symptoms persist, and more especially if there is frequent vomiting, operation may be undertaken It should also be carried out if there is any indication of the presence of a duodenal ulcer or gall stones If there is an ulcer a gastro enterostomy is indicated, as the treatment of the ulcer will usually bring about a cure but if there is no ulceration a duodeno jejunostomy will usually be the most satisfactory procedure

Operative technique.—The usual incision is made and the abdomen most carefully investigated for other lesions If the dilatation ends

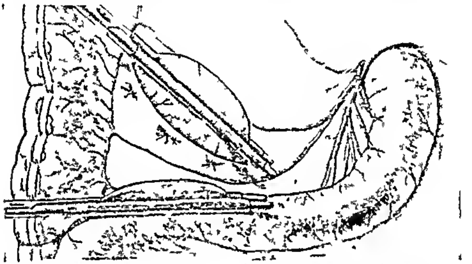


Fig 388 —Duodeno jejunostomy duodenum and jejunum clamped

abruptly at the level of the mesenteric artery the condition is more likely to be cured by operation, and this is also so if the muscular wall of the duodenum is hypertrophied If, on the other hand the dilatation tapers off into the jejunum and there is no definite evidence of mechanical obstruction, the results are less likely to be satisfactory The transverse colon being lifted upwards so as to expose the posterior surface of the mesocolon, the third part of the duodenum can be seen through the peritoneum running to the root of the mesentery and if it is distended will form a very definite prominence An opening is made in the mesocolon to the left of the ascending branch of the right colic artery which runs up to anastomose with the middle colic artery Care must be taken to avoid this vessel and the superior mesenteric vessels which lie to the left The third part of the duodenum is drawn through the opening in the mesocolon and if sufficiently enlarged, a small clamp may be applied in the long axis of the gut A loop of jejunum of a corresponding size and as near to the flexure as possible without causing tension is also clamped (Fig 388)

An anastomosis is then performed in a manner precisely similar to that used in a gastro-enterostomy, two layers of catgut suture being employed If the duodenum is insufficiently dilated to allow the application of a clamp, it is fixed at either end to the jejunum with sero-muscular sutures and sutured in the usual way In such cases, it is better to empty the stomach with a stomach tube before proceeding with the anastomosis The opening in the mesocolon is sutured to the duodenum above the anastomosis with a few catgut stitches and the abdomen is closed in the usual way The after-treatment will be identical with that for gastro-enterostomy

The results of operation depend upon the careful choice of cases Wilkie was very satisfied with his results and used to say "I know of no other abdominal operation followed by so smooth a course" Other observers have not been so satisfied In my own experience, if there is definite evidence of obstruction the symptoms entirely disappear after the operation, but when there is reason to believe that the condition is atonic, the results are not nearly so good, as discomfort and vomiting persist

CARCINOMA OF THE DUODENO-JEJUNAL FLEXURE

Rarely, a carcinoma may occur in this part of the intestine It is slowly progressive and will give rise to symptoms similar to those of pyloric obstruction but the vomited material will often contain bile The dilatation and hypertrophy of the duodenum may be enormous, and generally extend sufficiently far upwards to involve the stomach An X ray, however, usually reveals the dilated duodenum and the site of the obstruction At operation the dilatation is manifest and the tumour may be palpable In two such cases I have been able to free the flexure sufficiently to resect the tumour and to perform an end to end anastomosis In others the growth is more adherent and the resection becomes a prolonged and difficult operation of considerable risk If the growth is adherent or its removal would be too hazardous a duodeno-jejunostomy should be performed, and is carried out on precisely similar lines to that used for duodenal ileus

GASTRIC AND DUODENAL DIVERTICULA

Duodenal Diverticula

Diverticula of the duodenum have been often recognized of recent years Spriggs and Marxer, in a routine examination of a thousand patients, found them in 38 instances, the lesion being as common in men as in women In many cases no symptoms may be produced and the condition is only discovered accidentally on an X-ray examination for some other lesion In others, however, it may give rise to symptoms somewhat similar to those of a duodenal ulcer, that is, they appear late after food are relieved by food and often occur at night As a rule, however, in uncomplicated cases there is no severe pain but only a feeling of distention and fullness In other examples

the symptoms may be identical with those of duodenal ulcer and the condition be associated with ulceration either in the pouch itself or in the first part of the duodenum Not uncommonly there is then a visible loss of blood or occult hæmorrhage The diverticula are much more common in the second part of the duodenum In my own series of 17 cases only 2 were in the third part They may be situated on the outer, the posterior or the inner wall, in the last position burrowing into the head of the pancreas When on the outer wall they may lie flat on the surface of the duodenum and when covered by the peritoneum may be difficult to discover In all cases the wall is very thin, so that no muscular coat is as a rule visible to the naked eye

Indications for operation.—In cases only found accidentally it is manifest that no surgical interference is indicated There is on the other hand, no doubt that if left these diverticula do tend to increase in size If the patient has only mild symptoms of distention and discomfort, attempts may be made to reduce them by medical means but the results are not very satisfactory Spriggs advises that medical treatment should always be tried before operation The patient is carefully dieted and attempts made to drain the pouch by posture, and liquid paraffin is given as a lubricant If the symptoms persist in spite of medical treatment and cause inconvenience or if they are associated with repeated attacks of hæmorrhage operation should be undertaken

Operative technique.—Access is by the usual upper right paramedian incision After examination of the rest of the abdomen, the hepatic flexure is pulled downwards and to the left, and the outer wall of the duodenum is carefully explored Nearly always it will be found necessary to divide the outer layer of peritoneum and so mobilize the duodenum In several of my cases a pouch was found collapsed lying flat on the duodenal wall but was not visible before the peritoneum was divided A careful series of X rays beforehand will determine the site of the pouch, and they should be before the surgeon during the operative procedures If it is situated externally, two Spencer Wells forceps should be applied to its base and the pouch removed The opening is then carefully sutured with a through and through suture, care being taken to see that this passes through the muscular coat of the normal duodenum This suture line is then embedded by a second sero muscular suture A careful investigation should be made for a duodenal ulcer, and if this be found it must be treated by whatever method appears to be indicated If, after division of the outer leaf of the peritoneum, no diverticulum is discovered, an opening should be made in the anterior wall of the duodenum opposite the site of the pouch, as shown in the X rays, and a finger should be inserted, the opening of the diverticulum is usually then manifest Those on the inner side which burrow into the pancreas used to give rise to the greatest difficulty, a dissection through

the pancreas being often prolonged and associated with a high mortality. N. J. Maclean* has, however, devised an ingenious method which does away with most of the operative difficulties. The finger which has been entered through the duodenum passes into the pouch and pushes it upwards towards the anterior surface of the pancreas. The peritoneum over the pancreas and over the pouch is divided with a slight touch of a scalpel and, with careful stripping by a pair of forceps, the pouch with the surgeon's finger within it can usually be pushed out until it is quite free of the pancreas. It is then seized at the base with small Spencer Wells forceps, cut off and the opening sutured and embedded in the usual way. The pancreas is united with one or two catgut stitches and the opening in the duodenum is closed with two layers of continuous suture.

Results of operation.—The operative technique itself is relatively simple but many of these patients are poor subjects, old and fragile, in whom any operation is a bad risk, so that the operation has a higher mortality than would be expected. If, however, the patients are carefully prepared with a relatively prolonged rest beforehand, and the stomach and duodenum have been washed out, very satisfactory results will follow, the patients being entirely relieved.

Gastric Diverticula

Diverticula of the stomach are much less common than those of the duodenum. Whereas in my own series there were 17 cases of duodenal diverticula necessitating operation, there have been only three cases of gastric diverticula, although there have been several others in which an operation was not advised. These diverticula are often mistaken for penetrating ulcers of the lesser curvature. They are usually situated high up on the lesser curvature in close proximity to the opening of the œsophagus, and in my own experience have generally been on the posterior surface. They burrow backwards into the tissue above the tail of the pancreas and are usually very adherent. Because of the inaccessible position and the firm adhesions, operation for their removal is always a very serious and hazardous procedure. Their general pathological characteristics are identical with those of diverticula of the duodenum, and the fact that they progress in size and that their walls become thin and attenuated suggests that they are acquired. The symptoms are very similar to those of a gastric ulcer but, here again, instead of acute pain there is often only a feeling of distention and fullness after meals which may be relieved by vomiting. Hæmorrhage may occasionally occur owing to ulceration.

Indications for operation.—All these cases should be given very careful medical treatment before any operation is contemplated. In my own experience they are generally women who are bad operative risks: either thin and fragile or short and stout, and the operation has been one of very great difficulty. Hence it should only be under-

* *Surg Gyn and Obst*, July, 1923, xxxvii, 6.

taken if the symptoms are very severe, if the pouch has shown a rapid increase in size on X-ray investigation, if there is a fear of perforation or if there have been frequent attacks of hæmorrhage

Operative technique.—The abdomen having been opened and explored, the stomach is carefully examined for any ulceration Usually little or nothing abnormal is found on surface examination but, on opening the lesser sac, the posterior wall of the stomach may be found firmly adherent close up to the œsophagus and near the lesser curvature Access to the pouch can sometimes be more readily gained through the gastro-colic omentum and at other times through the lesser omentum If it can be reached in this way the adhesions around should be carefully dissected off until the pouch is free This may be very difficult, and in one of my cases could only be accomplished by opening the anterior wall of the stomach and inserting a finger into the diverticulum When free it should be picked up at the base, excised and the opening closed as with duodenal diverticula If there is any concomitant lesion, such as ulceration, at the lesser curvature this is treated at the same time

Results of operation.—These will depend almost entirely on the position of the pouch If it is low down or on the anterior wall and easily accessible the operation is one of ease and little or no disturbance will be caused If, however it is high up on the posterior wall the manipulation necessary for its dissection will be very considerable, and in these cases operation is associated with considerable risk Hence the operation is a grave and serious procedure and should only be undertaken if the symptoms are very distressing or there are severe complications

GASTRIC AND DUODENAL FISTULÆ

Internal fistulæ may occur between the stomach and the colon, usually as the result of marginal ulceration after gastro-enterostomy (*See* p 731) They are also sometimes seen with carcinoma of the stomach, in which case the growth is usually too far advanced for surgical treatment Similar fistulæ may occur between the duodenum and gall-bladder in cases of gall stones or carcinoma

External fistulæ are usually the result of injury produced at operation or the sequel of ruptured ulcer They may occur from the closed stump of the duodenum after partial gastrectomy—it was the presence of such a complication that caused me to abandon the insertion of radium after partial gastrectomy for carcinoma—or from the line of union after a Billroth I type of gastrectomy They have also been known to occur after right nephrectomy from injury to, or inflammation of, the posterior wall of the duodenum

With the leakage of gastric or duodenal contents the tissues of the abdominal wall are digested, and surgical interference becomes a difficult and serious procedure Fortunately many of these cases do well with the application to the wound of continuous suction which

removes the secretions before they can digest the tissues of the abdominal wall This method should always be tried before operation, most fistulæ from a closed duodenal stump will close Fistulæ occurring after anastomosis of the stomach and duodenum are much more serious and are usually fatal. In such cases a gastro-enterostomy may be performed but must always be combined with some form of pyloric occlusion For fistulæ after nephrectomy, which persist in spite of suction, the abdomen should be opened by a right paramedian incision, the peritoneum on the outer side of the duodenum incised and the duodenum carefully dissected from the adherent tissues behind it and turned inwards When the opening in the posterior wall has been completely freed it should be closed with two layers of sutures and separated from the inflamed tissues behind it by the interposition of a pad of omentum

PYLORIC STENOSIS

The common causes of pyloric stenosis are congenital hypertrophy in infants scarring from peptic ulceration and neoplasms The surgical treatment of these conditions is considered under the appropriate headings Rarely perigastric changes may cause an obstruction of the pylorus or first part of the duodenum, the commonest of these lesions are inflammatory or neoplastic changes in the gall bladder or in the head of the pancreas If the underlying cause cannot be removed the obstruction is best overcome by a posterior gastro enterostomy

In addition to these well recognized changes two other conditions have been described in the adult obstruction from muscular hypertrophy and from simple fibrosis There is no doubt that the first condition does occur but it is rare In my own series of 2 655 gastric operations there have been 7 in which there was definite obstruction with characteristic symptoms and dilatation of the stomach with hypertrophy of its muscular wall At operation the pyloric canal was much narrowed owing to a gross hypertrophy of the circular muscle Similar cases have been described by Russell Maylard, Bailey and McClure There is however, some divergence of opinion as to the cause Many believe that the hypertrophy is due to spasm for in many cases it is associated with ulceration of the stomach My own belief is that it is an example of a minor degree of congenital hypertrophic stenosis persisting to adult life for the pathological picture is identical with that found in infants and in my experience there is no evidence that spasm ever causes hypertrophy of involuntary muscle (e g cardiospasm and Hirschsprung s disease) Of the presence of simple fibrosis there is less evidence Cases have been described by Maylard where there was extreme narrowing with no muscular thickening and no visible scarring but the only cases I have met in my series have been transient and manifestly due to a temporary spasm

With any form of pyloric obstruction in the adult operation should not be long postponed The lesion is mechanical and can only be

cured by mechanical means The symptoms may be relieved by stomach washes but the relief is only temporary and the underlying condition may be carcinomatous and may progress to an inoperable stage In the case of muscular hypertrophy the operative procedure will depend upon its degree

Access is best gained by a right paramedian incision and the rest of the abdomen is carefully explored special attention being given to eliminate associated ulcer of the lesser curvature of the stomach If the hypertrophy is slight very satisfactory results follow pyloroplasty In two of my own cases this was performed by the Heineke Mikulicz method with complete satisfaction It allows exploration of the interior of the duodenum for ulceration and gives a free passage from the stomach to the duodenum If the muscular hypertrophy be greater it is not so satisfactory as the thickened muscle does not allow good transverse suturing even if a portion be removed If the diagnosis be certain complete relief may be obtained by posterior gastro enterostomy as in one of my own series Often however the hypertrophy is so great that the nature of the lesion may not be evident and the condition may be mistaken for a sarcoma or even for a carcinoma of the pylorus In this case a partial gastrectomy will be performed this was the operation selected in four of my cases The anastomosis may be completed either by the Billroth I or the Polya methods

GASTRO-JEJUNAL ULCERATION

Gastro jejunal or marginal ulceration is a characteristic peptic ulcer at the site of anastomosis It most frequently occurs after gastro enterostomy It is said to be more common after the anterior operation and less frequent after partial gastrectomy In my total series of 128 cases 109 occurred after posterior gastro-enterostomy 6 after the anterior operation 6 after partial gastrectomy and 7 were recurrences after local excision Of these 41 occurred in patients on whom I had personally performed the first operation In 1 152 posterior gastro enterostomies there were 37 cases that is 3 3 per cent Of these 896 were performed for duodenal ulcers with 36 marginal ulcers (4 per cent) Of 99 anterior gastro enterostomies 19 were for duodenal ulcers with 2 subsequent marginal ulcers (10 5 per cent) With 620 partial gastrectomies 28 of which were for duodenal ulcers there was one marginal ulcer (3 5 per cent)

The most important factor in their production has been clinically and experimentally proved beyond all question to be hyperacidity They are thus more common in males—of my own 128 cases only 8 were females—and are almost limited to operations performed for duodenal and pyloric ulcers 125 in my series were of this variety They are likely to occur in young men with a high acidity and for this reason a partial gastrectomy is more likely to be chosen for the treat ment of a duodenal ulcer in such a patient They are very common after and indeed almost certain to follow a Roux gastro-enterostomy

or gastrectomy, for here the alkaline bile and pancreatic juice is diverted from the anastomosis, these operations, therefore, should never be performed

Indications for operation.—By careful selection of the operative procedures in the primary operation much may be done to lessen the incidence of this serious complication It is generally assumed, I think incorrectly, that very little training is required to enable a doctor to perform a gastro enterostomy A great deal, however, is required to enable him to make a correct selection of the treatment for any individual case

Recurrent symptoms after a gastro-enterostomy for duodenal ulcer are most commonly due to gastro jejunal ulceration, and hæmatemesis or melæna in such a case is, I believe, nearly always so caused In doubtful cases the X-ray investigation is often of little value, but the flexible gastroscope used by a skilled observer will generally provide definite proof of the presence or absence of ulceration In the early stages or in doubtful cases medical treatment on strict lines should be employed with the abolition of all smoking, but, although the symptoms often entirely disappear while the patient is in bed on treatment, I am beginning to be very doubtful if a real cure ever results Nearly all the cases I have so treated have returned to me later and required surgical intervention

Operative technique.—Because the condition is due to a hyperacidity which has not been adequately neutralized by the gastro-enterostomy, any operation short of an extensive gastrectomy would be expected to be a failure, and such indeed has been my experience Of 18 cases treated by local excision and plastic operations seven showed recurrent ulceration

The wide resection and the poor state of the patient's health and the prolonged dissection necessary to divide old adhesions and restore the normal relationships, make this operation very difficult and severe The difficulty is enhanced where there is a gastro jejuno colic fistula, fortunately, with a free communication into the colon, the acid is often neutralized and the ulcer heals, so that the separation and closure of the fistula may for a time be successful As a rule the ulcer soon returns and will then require partial gastrectomy, but two patients are being closely followed in my follow-up department who have remained well for nearly four years after separation and closure of the fistula only

Because of the severity of the operation these patients must be most carefully prepared They should be kept in bed for one or two weeks on a careful diet with large quantities of fluid and glucose If the hæmoglobin is at all reduced a blood transfusion should be given

Gastrectomy and resection for gastro-jejunal ulcer—A right paramedian incision should be employed, not less than 5–6 in in length If it coincide with the old incision, the anterior sheath will have to be carefully dissected off the muscle in its whole length and the muscle

dissected off the posterior sheath There are usually a large number of adhesions, and therefore it will usually be wiser to open the peritoneum in the upper part of the wound There are less likely to be adhesions over the liver and, even if this viscus be adherent, a small accidental incision into it has no serious consequences When the peritoneum has been opened all adhesions must be carefully dissected off No attempt whatever must be made to correct the pathological lesion until the anatomy has been restored When the omentum colon and anterior surface of the stomach have been entirely freed from the anterior abdominal wall and the liver, the abdomen can be explored Gastro jejunal ulceration is made manifest either by a hard indurated mass or an area of speckling over the adherent mesocolon

The transverse colon is turned upwards and the mesocolon carefully dissected off the old anastomosis This is a slow and tedious procedure for the mesocolic arterial arch must not be injured or the transverse colon may be devitalized When the mesocolon is quite free, the anastomosis may be pushed up through it The gastro-colic omentum is now divided between ligatures down to the duodenum, and the pyloric artery is also divided in the manner usual with a partial gastrectomy The duodenum is similarly divided between clamps and, if the Polya operation is selected the distal end is sutured and embedded The stomach is pulled down and the lesser omentum containing the coronary artery is divided in the usual way The stomach can now be turned over to the patient's left and any adhesions between the ulcer, the anastomosis or the posterior wall of the stomach and the lesser sac are divided The stomach is clamped proximal to the anastomosis, as in the usual Polya type of partial gastrectomy, but the resection must always be wide so that the acidity be permanently abolished One of the drawbacks of this operation is that, owing to the anastomosis, the jejunum has to be opened before the new anastomosis can be completed and hence the possibility of infection is increased In some cases the jejunum may be divided below the anastomosis and the ulcerated area, the resulting opening closed, and either a fresh loop used for the Polya anastomosis or the operation completed by the Billroth I method Often, however, this double step entails extra time in an operation already prolonged and severe, and hence I generally prefer to use the opening in the jejunum for the new anastomosis In this case a clamp is passed across the jejunum If the ulceration is limited to the antimesenteric border of the gut, the clamp may be passed obliquely across, so that when the diseased area is excised one long opening in the antimesenteric border of the gut is left, but if as so often happens, much scarring has drawn the mesentery up into the base of the ulcer, the clamp is passed across a whole loop and when the diseased area is removed the gut is completely cut across and there is left in the clamp the openings of the afferent and efferent loops with a piece of mesentery between As the gut now lies, the afferent loop is near the lesser curvature of the stomach and the efferent loop near the greater curvature If the afferent loop is suffi-

ciently long the anastomosis is performed in this position as in the normal Polya operation but if at the previous operation a no-loop method had unfortunately been used I have no hesitation in rotating the loop and performing the anastomosis with the afferent loop at the greater curvature although this does slightly increase the possibility

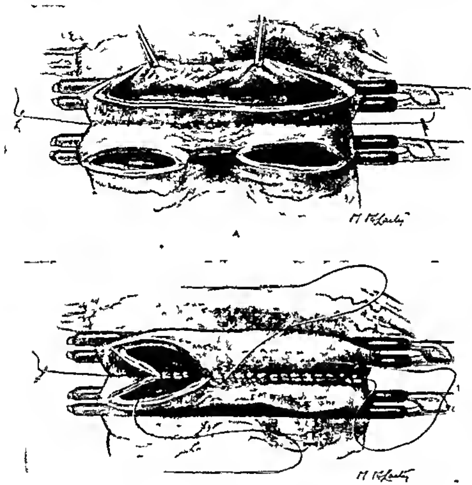


Fig 389 —Polya gastrectomy for gastro jejunal ulcer

A Sero-muscular suture uniting the two separate limbs of the jejunum, with the mesentery between them to the posterior wall of the stomach B The hæmostatic suture nearly completed

of subsequent constriction of the efferent loop by scarring of the mesocolon

The two clamps are now approximated and if there is a relatively long portion of mesentery between the two loops it is carefully sutured to control hæmorrhage It will now be found very useful to apply a series of Spencer Wells forceps along the proximal edge of the jejunum to evert it and facilitate the passage of the sero muscular suture the forceps being covered by an abdominal pad during the passage of

the suture If there is only a single long opening in the antimesenteric border of the jejunum, the stomach is opened after the passage of the sero-muscular suture and the anastomosis and the removal of the stomach are completed as in the usual Polya gastrectomy If there are two openings of the jejunum with a piece of mesentery between, the sero-muscular suture is passed in the usual way, i e a single suture is passed through the afferent loop of the jejunum and the lesser curvature of the stomach and tied, and a second suture is passed through the efferent loop and the greater curvature of the stomach, thus fixing the ends of the anastomosis The lower suture is now passed from below up as a continuous sero muscular suture, but in the centre picks up the serous coat of the mesentery instead of the gut (Fig 389, A) The stomach is now opened and the posterior layers sutured with a continuous through and-through suture which in the centre again picks up mesentery instead of gut The anterior layers are sutured in a similar way, the centre portion of the stitch in this case uniting mesentery to anterior wall of stomach (Fig 389 B) The clamps are then removed and the anterior sero muscular suture is inserted which again in its centre part unites the peritoneum of the mesentery to the anterior serous wall of the stump of the stomach By working in this way and ignoring the fact that in the centre there is no gut but only mesentery, the union is bound to be correct and a figure of 8 union is left, both walls of the stomach being united in the centre and the afferent and efferent loops joining with the stump of the stomach near the two curvatures The transverse colon is again turned up and the opening of the mesocolon which is often large, is carefully sutured to the stump of the stomach If the afferent loop was short and had of necessity to be united to the greater curvature, it may be impossible to unite the mesocolon above the efferent loop In this case its edges should be inverted and carefully sutured to the efferent loop of jejunum, care being taken to cause no constriction The abdominal wound is now closed in the usual way, two or three tension sutures usually being required

Results of operation.—This operation is always serious and may, indeed, be the biggest operation in the abdomen The patients are nearly always bad risks, being reduced by severe pain, vomiting or repeated hæmorrhage If there be a colic fistula their strength has often been further exhausted by severe diarrhœa Nevertheless, because the condition is progressive and the patient's life a misery, the surgeon can feel that he is justified in advising an operation even if it be associated with considerable risk, and if the patient does survive there is every probability that he will be restored to normal health Most of the published statistics show a mortality of approximately 30 per cent, but there is no operation in which the mortality is so reduced by experience and care Of my series of 128 cases 99 have been treated by partial gastrectomy In these the total mortality was 29 per cent, but in the later cases of the series there were 10 with a mortality of just under 10 per cent

BENIGN TUMOURS OF THE STOMACH

Until a few years ago benign tumours of the stomach, which are rare were not diagnosable before operation Although they may be recognized to-day by the aid of X rays and the flexible gastroscope, they rarely give rise to characteristic symptoms, so that although there may be severe attacks of pain, hæmatemesis or more rarely a tumour, the condition is often mistaken for some other lesion, or may be accidentally found at operation in association with some other lesion

If found at operation such tumours should always be removed, as they may later cause severe hæmatemesis and anæmia If diagnosed by X-rays or the flexible gastroscope, the decision to operate will depend upon the severity of the symptoms and the age of the patient A pedunculated tumour in the region of the pylorus may cause severe pain of a colicky nature as the result of being gripped by the pylorus in the peristaltic wave, others may cause repeated hæmatemesis and severe anæmia With such symptoms a benign tumour should always be considered as a possible cause, and if its presence be demonstrated an operation is advised Small tumours shown by filling defects in the body of the stomach may, if their symptoms be slight, be watched, but it must always be remembered that they may become carcinomatous

Operative technique.—The abdomen is opened in the usual way and the viscera are explored If a papilloma has been diagnosed by the X rays it is nearly always possible to palpate it through the stomach wall, and it will then generally be found to be fairly freely movable owing to the length of its pedicle An incision should be made through the anterior gastric wall and the tumour pulled up It may be excised with the cautery or knife and the resulting opening in the mucosa carefully sutured If the tumour be large it may be wise to transfix and ligature the pedicle before division The opening in the anterior wall of the stomach is then sutured with two layers of chromic gut The more sessile tumours, such as the myomata, either form firmer masses projecting into the lumen of the stomach or grow outwards into the peritoneal cavity, in which case they are easily visible The latter variety may grow to enormous masses which are mistaken for ovarian tumours In this type a distinction has to be carefully made from sarcomata If the diagnosis be doubtful a partial gastrectomy should be performed, but if there be no doubt that the tumour is benign it is usually sufficient to remove a small ellipse or wedge-shaped portion of the stomach wall to which the tumour is attached, and to close the resulting opening with two layers of suture

CARCINOMA OF THE STOMACH

Indications for operation.—Carcinoma of the stomach is not only very frequent but also steadily progressive, and at present the only hope of cure lies in surgical interference Even with the most careful and complete investigations which are to day at the disposal of the surgeon, a large number of cases are unfortunately still inoperable

when they come for treatment In my total series of 507 cases, an attempt at a radical cure was only possible in 36 per cent , but it is of interest to note that in the cases seen in the last nine years this percentage has risen to 44 As with carcinoma elsewhere, an operation is only likely to be successful if the whole of the growth and the lymphatic fields involved are completely removed, together with the lymphatic glands into which these fields drain The operation is therefore extensive, and since many of the patients are elderly and have had their resistance much reduced by severe pain interference with digestion repeated vomiting and hæmorrhage, the mortality is bound to be high In my own series, and this is true in most of the reported statistics the mortality was about 28 per cent For this reason there are still physicians who believe that an operation should only be undertaken in exceptional cases Although without operation a patient may continue to live for a year or eighteen months his life during this period is one of profound misery and discomfort, and thus even an operation with a high immediate mortality is justifiable if it gives a fair hope of radical cure Only a few years ago the cases that survived operation with no evidence of recurrence were so few that the pessimistic view might have been justified but it is becoming more and more evident to day that not only will a partial gastrectomy often give a very considerable period of relief but that an increasing number of cases have lived sufficiently long without evidence of recurrence for them to be regarded as cures Of my own 507 cases 6 1 per cent are alive and well with no signs of recurrence for five or more years , of those in whom a gastrectomy was possible the percentage is 17 2 and in those that survived the operation the figure has risen to 23 5 These figures although relatively low, are sufficient to encourage surgical treatment and make us feel that with an operation there is a definite chance of a cure, whereas if no operation is performed the disease is steadily and rapidly progressive It is my own custom, therefore, to advise operative treatment for nearly every patient in whom there is no definite evidence of metastases It is true that over the age of 70 the normal expectation of life is so short that one is not justified in advising a serious operation, as the gain might be very little more than the time that they would live without operation There is also another consideration , if the patient has been operated upon for a known carcinoma and the condition is found to be inoperable, the relatives will feel that he had at least been given every chance, and their anxieties will be relieved to the extent of knowing that no opportunity has been missed In addition to these cases in which an operation is undertaken with a definite hope of accomplishing a cure, there are those to whom relief may be given by a palliative procedure to overcome pyloric obstruction It can be said, therefore, that the indications for operation are definite, and that every patient should be given the chance which this method affords unless there is positive evidence, from secondary deposits, that the condition is beyond hope

Preparation for operation.—These patients are often fragile, wasted

and dehydrated and may therefore be much improved by careful preparation but on the other hand valuable time must not be lost They should be kept in bed on a careful diet for a few days or at most a week before operation The blood should be examined and grouped and if there is a definite secondary anaemia a transfusion of 350–500 c c of blood should be given on the evening before the operation In all cases fluid and glucose should be given in large quantities by mouth or by rectum or in exceptional cases intravenously If the patient is sleeping badly a narcotic may be administered at night during this period The bowels must be kept open but no drastic aperient administered The choice of anaesthetic will be on similar lines to that for a gastric ulcer my own preference being for gas and oxygen with a little open ether or pentothal other surgeons prefer infiltration and local anaesthetics

Operative technique Partial gastrectomy —Wherever possible a partial gastrectomy should be performed This differs from the operation for gastric ulcer in the extent of the stomach removed and in the clearance of the lymphatic glands Most carcinomata commence in the lesser curve or at the pylorus and therefore a wide removal must be carried out so that the two lower lymphatic fields (*see* Fig 354 p 674) are completely eradicated If the growth has spread to the lymphatic field of the fundus as a general rule it has also spread so widely to the glands the peritoneum or liver that any radical operation is out of the question In all cases the lymphatic glands must be freely removed The gastro colic omentum may be divided near the colon but many surgeons advocate the complete removal of the great omentum It is not my custom to carry this out as a routine but if there is wide involvement of the lymphatics passing down into the gastro colic omentum it is certainly wiser to remove the whole omentum The glands behind the pylorus lying upon the head of the pancreas must be freely taken away and with growth at the pylorus this may mean a somewhat prolonged and careful dissection The lesser omentum must be divided as close to the oesophagus as possible so as to remove all the lymphatic glands along the lesser curvature and it is my own custom to open the peritoneum of the lesser sac at the upper border of the pancreas and gradually to dissect up towards the stomach the glands lying around the coeliac axis the coronary artery then being divided close to this (Fig 390) Because of the wide removal of the stomach the Polya method of resection may be more suitable but if the fundus be sufficiently movable the Billroth I operation may be selected as it has a rather lower mortality but the amount resected must never be limited in order to make this operation possible It is partly because of these extensive but necessary dissections of the glands, that the mortality of a gastrectomy for carcinoma is so much higher than that for an ulcer

The abdomen should be opened by the usual right upper paramedian incision A rapid but careful investigation must then be made of the whole of the abdominal viscera to determine whether the growth is

removable It is my own custom to pass the left hand down into the pelvis The omentum peritoneal wall and pelvic cavity can then easily be felt for any secondary nodules on the peritoneum which are more frequent perhaps in the floor of the pelvis than elsewhere The right and left lobes of the liver are palpated for secondaries and the stomach is drawn out and the extent of the growth investigated If it is adherent

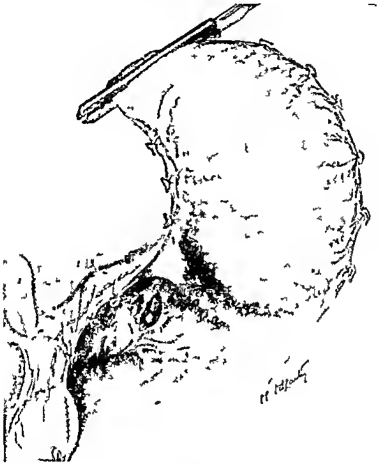


Fig 390 Ligature and division of the coronary artery close to its origin from the cœliac axis

to the pancreas the chance of cure is almost negligible but involvement of the transverse colon or an adjacent loop of small gut does not always mean that the case is inoperable and the same is true of adherent gall bladder The resection of a loop of transverse colon of a loop of small intestine or of the gall bladder of necessity adds to the risk of the operation but now and again satisfactory results are obtained and the patients remain free from recurrence for a prolonged period

The lymphatic glands are then carefully examined It is often a disappointment to find that a growth which is otherwise removable may be associated with large masses of glands running up from the

cœliac axis round the abdominal aorta and making a radical cure impossible, but if it is possible to reach above the enlarged glands of the lesser curvature and there are only one or two glands around the cœliac axis, the tumour may be considered suitable for removal In certain cases the growth has spread to the mesocolon If this area can be isolated and excised without injury to the vessels passing to the transverse colon, it is no contra indication to operation but if the middle colic artery is involved it will mean resection of a portion of this vessel and eight or nine inches of the transverse colon may then have to be removed In several of my own cases I have divided this artery and have found a colonic resection unnecessary, but in other cases I have had to remove a portion of the colon, every case with such an involvement must be carefully judged as to whether it is justifiable to proceed with this measure

If the growth is removable, the gastro-colic omentum should be divided or the greater omentum removed In the former case an opening is made into the lesser sac just above the transverse colon, and the gastro colic omentum is divided between ligatures down to the duodenal cap as close to the transverse colon as possible In the latter case the great omentum is turned upwards, an incision made through the peritoneum at the upper border of the transverse colon, and the line of cleavage sought between the mesocolon and the great omentum This is not, as a rule, difficult to find, and the transverse colon with its mesentery can often be stripped downwards until it is quite free The great omentum is then divided between ligatures at its upper and lower borders In the lower border the division is carried to the duodenal wall below the pylorus A finger is now inserted behind the pyloric canal and made to emerge through the lesser omentum The lower portion of the lesser omentum, including the pyloric artery, is now divided between ligatures The next step will depend upon the amount of involvement of the retropyloric glands With a growth close to the pylorus they may be considerably involved, and will have to be dissected carefully from the head of the pancreas until the posterior wall of the duodenum beyond them is quite clear Care must be taken in this step that the neck of the pancreas is not injured The duodenum having been freed, it is clamped in two places, the proximal clamp being about ½ in beyond the pyloric sphincter The duodenum is divided between the clamps and the distal end is closed with two lines of catgut sutures, and then embedded as in the operation for gastric ulcer If a Billroth I method is chosen it is left clamped and covered with gauze but unsutured The stomach is now turned over to the patient's left and any peritoneal adhesions in the lesser sac are freely divided The next step consists of the removal of the glands around the cœliac axis and the division of the coronary artery The stomach being turned to the left and lifted up, the posterior layer of the lesser sac is divided at the upper border of the pancreas. The coronary artery is then seen arising from the cœliac axis All lymphatic glands are dissected up towards the stomach, and the artery is divided between

two ligatures close to its origin (Fig 390) The stomach being turned over and pulled down the lesser omentum is divided between two ligatures close to the œsophagus the ligature on the upper end being left long as in the operation for gastric ulcer The gastro-colic omentum is divided between ligatures up to the site of division of the stomach The operation is completed as for a gastric ulcer but the gastric clamp is usually placed higher and a larger portion of stomach is removed The resected portion must include the whole of the two lower lymphatic fields Along the lesser curvature it should lie close to the œsophagus and should pass down to join the margin of the greater curvature at right angles or may lie even higher The operation is completed as for a gastric ulcer either a retro or anterior colic anastomosis being performed or united to the end of the duodenum In the former the divided mesocolon is carefully sutured to the stump of the stomach and the wound is closed

Postoperative treatment—This will follow the lines laid down for peptic ulceration but collapse may be more in evidence and transfusion either of saline or blood is more likely to be required In severe cases a blood transfusion may often be of the greatest value

Total gastrectomy—Total gastrectomy is not often indicated for if the growth has spread sufficiently widely in the stomach wall to necessitate total removal there will as a rule be secondary deposits elsewhere or widespread glandular involvement There is however one variety which grows slowly and widely infiltrates the stomach wall while leading to few if any deposits in the glands or elsewhere This is the so called leather bottle stomach For this condition total gastrectomy is indicated and although an operation of very considerable mortality many successful cases have been reported Most of the deaths occur from leakage at the site of the anastomosis due to the precarious blood supply of the lower end of the œsophagus which is largely derived from the stomach vessels For these reasons the operation is much safer if a fringe of stomach at the cardia can be spared

The early stages of the operation are precisely similar to those of partial gastrectomy but should include division of the falciform and left coronary ligaments of the liver with displacement of the left lobe of the liver to the right The duodenum is divided and the distal end invaginated the glands are stripped off the cœliac axis and the coronary artery is divided between ligatures The gastro hepatic omentum is divided between ligatures right up to the œsophagus The division of the gastro-colic omentum between ligatures is now continued up to the fundus the division passing into the gastro splenic omentum This structure is divided in small portions each being made accessible by drawing the stomach downwards and to the right The division is continued until the whole fundus is free The stomach is now turned upwards over the chest so that the posterior surface of the intra abdominal œsophagus is visible an opening is made in the mesocolon and a loop of jejunum is drawn up through it or if preferred

this loop may be turned up in front of the colon A position on the loop is carefully selected which can be brought into apposition with

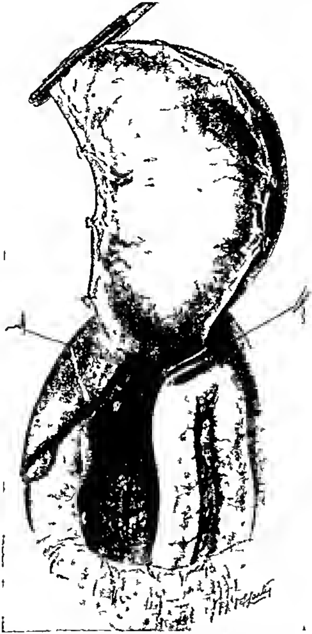


Fig 391 Total gastrectomy Method of anastomosing œsophagus to top of jejunum.

the œsophagus without tension It will generally lie 8–10 in from the flexure The walls of the œsophagus and jejunum are then sutured with a continuous catgut suture which does not enter the lumen of

either viscus The posterior wall of the œsophagus is divided ½ in distal to this line of suture, and a corresponding opening is made into the jejunum These two posterior layers are then firmly united by a continuous through and-through catgut suture (Fig 891) The anterior wall of the œsophagus is now divided and the stomach removed It will often be useful at this stage to pass a full sized œsophageal tube down the œsophagus into the distal loop of the jejunum this acts as a splint and facilitates the rest of the suturing The two anterior walls are united by the through and through suture, and this layer is embedded by the sero muscular suture Balfour advocates a lateral anastomosis between the afferent and efferent loops and a jejunostomy below the lateral anastomosis It is my custom not to perform these steps but to leave the œsophageal tube in position for 4–6 days

Postoperative treatment and results —The mortality from this operation is high The cases are few but the mortality from published results is from 40–60 per cent The after treatment must be carried out with meticulous care For forty eight hours water and glucose are given by rectum and fluid or blood may be required intravenously After forty-eight hours fluids may be cautiously given in 1 drachm doses by mouth or down the œsophageal tube, and only slowly increased Even when the patient has recovered from the operation the meals should be small and frequent The chief danger, apart from recurrence, is the later development of a severe macrocytic anæmia owing to the removal of all gastric secretions

Palliative operations —In certain cases a partial gastrectomy may be the most suitable palliative operation If for instance, there is a large fungating mass in the stomach which is freely movable but there are one or two small secondary deposits in the liver or elsewhere, a resection of a portion of the stomach may give great relief and comfort and is clearly the operation of choice

Gastro enterostomy —If there is a carcinomatous mass at the pylorus which is too extensive for removal or is associated with metastases but at the same time is causing great obstruction much relief to the vomiting and discomfort may be obtained by the performance of a posterior or anterior gastro-enterostomy, although the span of the patient s life is rarely increased thereby and the operation owing to the patient's poor state of health has a high mortality The details of the operation will differ in no way from that performed for benign stenosis of the pylorus

Gastrostomy —When the carcinoma is at the cardiac end of the stomach or in the œsophagus the dominant symptom is inability to swallow, and the patient is in danger of dying from starvation In such cases gastrostomy may be necessary either as a palliative measure or as a preliminary to local treatment of the growth by operation or with radium With benign stenosis of the œsophagus a similar operation may be required as a temporary or permanent measure

Many different methods of performing this operation have been devised, all of them aim at forming a satisfactory valvular opening

muscular coats around the catheter and about ½ in in distance from it (Fig 392) The catheter is pushed inwards as the silk stitch is tied, and carries with it a cone of stomach A second purse string stitch is then passed ½ in external to the first and is again tied as the catheter is invaginated By this means a cone of stomach wall 1 in in length is pushed into the stomach cavity and later forms an efficient valve The stomach is firmly fixed to the posterior rectus sheath by two silk sutures and the rectus, anterior sheath and skin are sutured above and below the rubber catheter If the patient is dehydrated or starved, feeding can be supplemented through this catheter as soon as he has recovered from the anæsthetic These patients require sufficient quantities of a well balanced liquid diet The feeds must be given slowly and at regular intervals For psychological reasons, small quantities of food should be given by the mouth

When this operation was only performed after the patient had become greatly dehydrated it was a measure of considerable risk Even to day it carries with it a high mortality as many of the patients have not sought advice until there is grave difficulty in swallowing In my own series of 128 cases there were 20 deaths a mortality of 17 per cent, but in the last 95 cases where the operation was performed earlier, the mortality had dropped to 8 per cent In only one of these cases was there any difficulty from leakage of the gastrostomy opening

Jejunostomy—A somewhat similar operation is often advocated whereby an opening is made into a high loop of jejunum This is often satisfactory in duodenal fistula, and has been strongly advocated in the treatment of very extensive gastric ulcers high up on the posterior wall which are either inoperable or would require a total gastrectomy for their cure In such cases, however, my own preference is for a gastro-enterostomy which will generally cause a great diminution in the size of the ulcer and may sometimes effect a cure Jejunostomy is occasionally used in the treatment of carcinoma of the stomach where the lesion is so extensive that neither a gastro-enterostomy nor a gastrostomy can be employed and it has been advocated as a temporary measure after complete gastrectomy

A loop of jejunum is selected, about 10–12 in from the duodeno-jejunal flexure, and a small opening is made in it into which a No 12 rubber catheter is sutured The operation is completed either by the insertion of two purse-string sutures, as in gastrostomy, or by means of a longitudinal valve made by approximating the walls over the catheter by silk sutures for a distance of about 1½ in as in the performance of a Witzel gastrostomy (Fig 393) If the lumen of the bowel appears to be narrowed by the buried catheter it is wiser to make an entero-anastomosis in order to short-circuit the loop in which it lies

FOREIGN BODIES IN THE STOMACH

The foreign bodies most commonly found in the stomach to day consist either of single articles swallowed by accident or multiple bodies

swallowed by hysterical women or by ignorant men for a wager A few years ago large masses formed by the aggregation of small pieces of material were common They were known as bezoars and the commonest was the hair ball but with the universal fashion of short hair for women these have disappeared Similar bodies formed by the swallowing of cotton wool or shellac used in industry have become rare with the better education of the operatives

When a patient swallows a single body he is generally aware of the accident and seeks advice If the body is smooth such for instance as a coin or metal whistle it will usually pass without incident Such may also be true of sharper bodies such as tooth plates if they have safely negotiated the œsophagus Fortunately the majority of such articles are opaque to the X rays and their position can therefore easily be noted If they are causing no symptoms the patient should be watched and operation only undertaken if the object becomes fixed or begins to cause symptoms Foreign bodies swallowed by design may be so multitudinous that they cannot be passed and an operation becomes necessary

Operative technique—The stomach should be exposed by the usual upper right paramedian incision and very carefully examined to ascertain if the foreign body has perforated the gastric walls The stomach itself is then carefully palpated and the foreign body located An incision should be made in the stomach walls after the abdominal cavity has been packed off It should be more or less vertical and large enough to enable the foreign body to be withdrawn without damage to the stomach wall The foreign body is removed with forceps and the wall of the stomach closed with two layers of catgut sutures the first passing through all the layers and the second only through the sero muscular walls The abdomen is then closed in the usual way The after treatment will be similar to that for operations for peptic ulcers

CHAPTER XVI

OPERATIONS ON THE LIVER AND ITS EXCRETORY APPARATUS

By G. GREY TURNER

Surgical anatomy of the liver. Mobility.—This organ is normally possessed of considerable mobility. It descends in the erect posture and recedes under the dome of the diaphragm when the recumbent position is assumed, and it moves laterally with the body. When the abdomen is opened for surgical purposes this mobility allows the organ to be displaced inwards and forwards and to be so rotated on its horizontal axis that its under-surface can be made to look almost anteriorly. In this way the hilum (the portal or transverse fissure) and the deeper ducts are made accessible. This normal mobility varies and is often interfered with by adhesions or by other pathological conditions which shorten the ligaments or make them rigid.

Position.—The position of the liver varies in different types of individual. In tall spare subjects with narrow chests the organ is commonly high up under the dome of the diaphragm and is then difficult of access. In the broad chested the costal margin is splayed out, the arch of the diaphragm flatter and the liver correspondingly more easily exposed. These natural variations must be borne in mind when the gall bladder is visualized by cholecystography, for its position varies with that of the liver.

Consistence.—The organ is normally plastic and this quality is of importance surgically because by gentle but firm, slow pressure a good hold may be taken without doing harm. The plasticity is largely due to the amount of blood which the liver contains. For the same reason the organ is friable, its integrity largely depending upon its tough, strong capsule.

Blood-vessels.—For the most part the blood is contained in the hepatic veins. These are simply spaces lined by endothelium; they are without valves, and are not collapsible. The amount of blood they contain is large, but it is under very low pressure. The branches of the hepatic artery are comparatively few; they run with the portal vein, and are the only vessels in the liver which spout when cut.

Relation of the pleura to the liver.—The pleural recess descends to within an inch of the costal margin and, whatever the position of the lung, this recess never varies, so that to reach the dome of the liver from the thoracic parietes the two layers of the pleura must always be traversed. It must be realized that the dome of the liver and the summit of the diaphragm are surrounded by the base of the lung and by the pleural sac. These points are illustrated in Fig. 891.

Morison's pouch, or the hepatic pouch, is that part of the peritoneal cavity which lies just below the right lobe of the liver. It is bounded inferiorly by the ascending layer of the transverse mesocolon and the hepatic flexure, internally by the peritoneum covering the spine, the free edge of the gastro hepatic omentum and the foramen of

Winslow between the two The fluid from a leaking gall bladder or common duct is apt to collect in this area (Fig 395)

Anomalies—Variations of surgical importance are exceedingly uncommon A tongue shaped process springing from the lower border of the right lobe is occasionally present Sometimes it is so large as to form a separate mass then known as Riedel s lobe It may have a broad connection with the liver or may be attached by a narrow thin pedicle This lobe may hide the gall bladder or the latter may be attached to it

Surgical anatomy of the gall bladder and biliary ducts—The fundus of the gall bladder usually lies behind the tip of the ninth costal cartilage The latter may be very difficult to identify in the obese and in such subjects a very useful surface marking is the point where a line drawn from the left anterior superior iliac spine through the umbilicus reaches the right costal margin (John Clay) When pathologically distended the neck of the gall bladder becomes very prominent

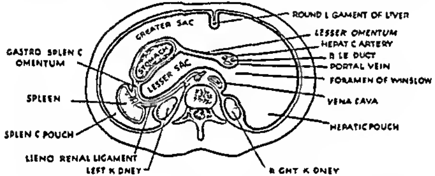


Fig 394 Transverse section of the peritoneal cavity at the level of the foramen of Winslow

at its lower border and is known as the infundibulum or Hartmann s pouch This part of the gall bladder is most important for it lies over the cystic duct which it may obscure and it is this part of the viscus which most readily becomes adherent to the duodenum The ducts are seldom found as they appear in the majority of anatomical diagrams in which they are shown dissected from the surrounding tissues and straightened out similarly the measurements usually given refer to the ducts when thus dealt with The supraduodenal portion of the common duct is usually covered by the duodenum and is frequently completely hidden by adhesions between the infundibulum of the gall bladder and the bowel forming the cholecysto-duodeno colic ligament It can however always be easily exposed by separating pathological adhesions and by gently drawing the duodenum downwards by gauze stripping When not distorted by contained calculi the lower end of the common duct tapers rapidly towards its narrowest part Attention must be drawn to the frequency with which small vessels both arteries and veins cross the common duct either to

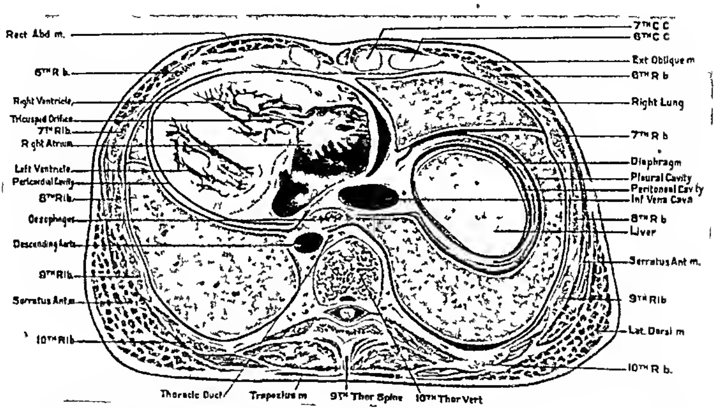


Fig 395 —Transverse section at level of tenth thoracic vertebra showing dome of liver completely surrounded by peritoneum diaphragm lung and pleural cavity

(Reproduced by permission from An Atlas Illustrating the Topographical Anatomy of the Neck Thorax Abdomen and Pelvis by Johnston Symington)

reach the head of the pancreas or the cystic duct and gall bladder (Fig 396)

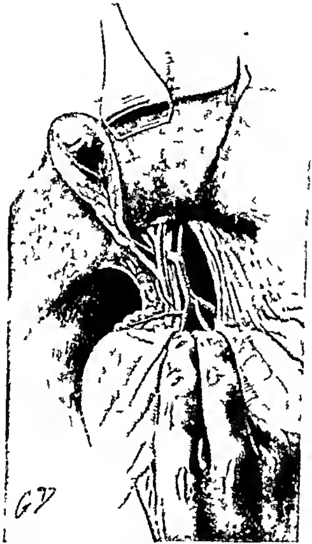


Fig 396 Anatomy of the biliary ducts their relations to blood vessels and exposure of the common duct obtained by traction on the duodenum.

Anomalies — The gall bladder is nearly always in its normal situation but it frequently presents the minor alterations shown in Fig 397 Very rarely it may be entirely absent or may be situated on the under surface of the left lobe or may be in its normal situation but entirely embedded in the liver substance or it may be either double or divided by a septum into two parts The ducts present endless variations (Fig 398) the most important being (1) a long cystic

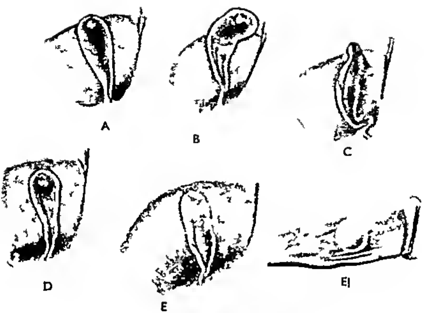


Fig 397 —Usual types of gall bladder

A As most commonly fo n l *B* Pendulous *C* W th a mesen ery *D* H d l n *E* Buri d *E1* Upper surfa e of ype *E*

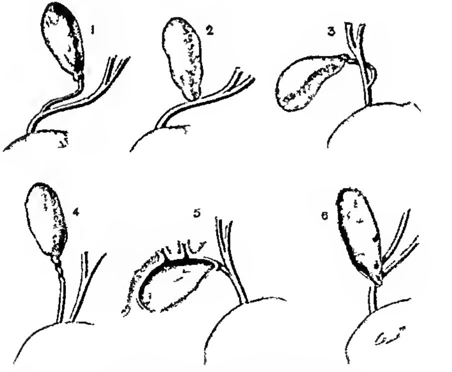


Fig 398 —Some anomal es of b le ducts

1 Long cyst c d ct running pa ll l to om mon duct before un g 2 Very short cys c d ct 3 Sp ral arrang ment of cys c d t 4 Cys ic du t open ng n lependen ly in o d odenum 5 Accessory hepa ic ducts opening d rectly n o gal bl d ler 6 Hepatic ducts opening directly in o gal bladder and common d t ar na g from lat er

duct running parallel with the common duct for a considerable distance (2) a very short cystic duct (3) various spiral arrangements in which the cystic duct winds round the hepatic ducts before uniting with them (4) variations in union of the hepatic ducts the latter either uniting much lower than normal or opening separately into the duodenum (5) accessory hepatic ducts (6) hepatic ducts opening directly into the gall bladder and the common duct originating from the latter There are also many alterations in the ducts which are pathological but which may be mistaken for anatomical variations The relations of the hepatic artery and its cystic branch are very variable Of 100 subjects examined by E R Flint of Leeds in only 84 was the arrangement of the ducts and vessels that usually described as normal In about 30 per cent of subjects the right hepatic artery or the cystic artery was found crossing in front of the common duct or the common hepatic duct and in 16 per cent an accessory cystic artery was found passing in front of the ducts to the gall bladder For these reasons the surgeon when operating on the neck of the gall bladder or the common duct must always satisfy himself of the exact relationships by actual visual observation

OPERATIONS ON THE LIVER

Suture of the liver—This may be necessary in many circumstances quite apart from deliberate resection as for instance when the liver is accidentally torn during cholecystectomy The suture material ought to be catgut—for big tears No 3 for smaller tears No 1 It must be passed with a round needle of sufficient size of eye to allow the catgut to follow without tearing too big a hole Special blunt flexible needles are sometimes recommended (Konsnetzoff) but though certainly convenient they are not really necessary and as they are not often required they are usually missing when wanted Most of the hæmorrhage is from branches of the hepatic veins and readily ceases when the liver surfaces are brought together Spouting vessels will be branches of the hepatic artery and should be caught and tied with catgut like any other vessel but bleeding from big veins may have to be controlled by passing a purse string suture round the opening as shown in Fig 105 *the flow being temporarily controlled* by putting the finger tip on the orifice of the vein The edges of the wound may be drawn together with as many stitches as are necessary to secure rough apposition about one to the inch being required for this purpose The needle is inserted ½ in from the edge of the tear should reach nearly to the bottom of the wound to be closed and must usually be brought out in the middle of the tear and re inserted so as to appear at a corresponding point on the opposite side of the wound These sutures are gently drawn together the knot of the stitch being kept at the side rather than over the centre This suture will bring the depths of the wound together and will stop most of the bleeding Exact apposition is then secured by stitches of finer catgut passed

close to the edge, at intervals of about ½ in. These sutures should be interrupted, because it is important to avoid the development of a hæmatoma in the liver wound, and it is much better that any oozing should find its way to the surface. When the capsule is deficient, or unusually friable, the sutures may not hold, and it may then be necessary to use some structure to support the stitch, after the plan of the old-fashioned "button suture." For this purpose magnesium plates have been recommended, but they may not be at hand when required, and it is better to rely on some structure which is always available. If the tear is on the upper surface of the liver it may be possible to pass the sutures through the triangular ligament; or the latter may be detached and laid over the proposed line of suture, so that the stitch is passed through it on both sides. Or a strip of the ligament may be cut away and used for this purpose in any situation, or a piece of parietal peritoneum or rectus sheath, or a portion of omentum, may be utilized. (Fig. 399.) (*See also* pp. 774–777).

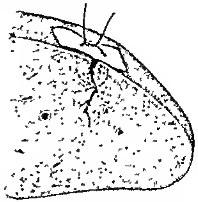


Fig. 399.—Suture passed through piece of triangular ligament that has been completely detached for the purpose.

Operations for Fixation of the Liver

Indications.—True hepatoptosis is very rare, and mild degrees of prolapse of the liver are only part of a general visceroptosis and can rarely justify surgical intervention. Operative treatment may be indicated when a definite displacement causes troublesome symptoms which cannot be relieved by palliative means such as support by belts; or when there is reasonable doubt of the diagnosis; or when a displaced liver is associated with some other condition which may be relieved surgically. Intervention is very rarely indicated, but the possible methods illustrate the principles of the technique of fixation of any abdominal viscus, and may therefore be included here.

Choice of operation.—The methods available are:
(1) Formation of adhesions between the liver and the parietes.
(2) Shortening of the ligaments. (3) Direct suture to the parietes.
(4) Gauze packing.

Technique.—In the thin subject the best incision is a vertical one, either through the rectus or the middle line, but in big and stout patients the oblique incision of Kocher is more convenient. In every case the first stage of the operation must be a careful scrutiny of the conditions present, combined with a search for any other pathological process which may have contributed to the symptoms. If the condition is an uncomplicated prolapse, the surgeon must decide what

method of fixation is to be employed Mild degrees may be treated by any of the methods mentioned but for severe cases a combination will certainly be required

(1) **By the formation of adhesions**—An attempt may be made to bring these about by rubbing the surface of the liver and the opposing parietes with some such substance as pure carbolic tincture of iodine or perchloride of mercury (1 in 500) As a first step a gauze swab must be introduced behind the posterior part of the liver in such a position as to catch any excess of the irritating chemical which is applied on a swab of dry gauze held in a sponge handle The upper surface of the liver and the adjoining dome of the diaphragm and parietes are thoroughly rubbed special care being taken to apply it to the angles where the ligaments are attached

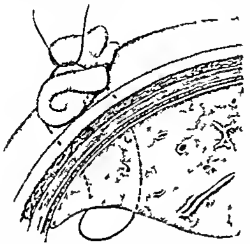


Fig 400 Fixation suture passed through liver and parietes and tied over roll of gauze In the figure it has not yet been drawn tight

(2) **By shortening ligaments** —Only the triangular and round ligaments can be dealt with and reefs must be taken in them by catgut sutures This method is not enough in itself and must be combined with some plan to deal with the inward and downward displacement of the right lobe

(3) **By direct suture.**—For this purpose thick catgut sutures (No 5 chromic) are passed through the liver substance about an inch from its anterior edge on the one hand and deeply into the parietal tissues getting a good hold of the muscle or of the costal margin on the other A more convenient plan is to pass the sutures right through the parietes the two ends being brought out at an interval of an inch and being tied over little rolls of gauze (dossil) as in Fig 400 Three to six of these sutures are all that can usefully be employed and the same precaution must be taken to see that the liver lies in its proper position before they are tied and the abdomen closed

(4) **By gauze packing**—In this method an attempt is made to produce granulation and subsequent adhesions between the surface of the liver and the parietes by the contact of gauze packed into the interval between the liver and the dome of the diaphragm It is gradually removed commencing about the eighth day

After treatment—The foot of the bed must be raised on blocks 9 in high and must be kept so for a month or six weeks during which time the patient remains strictly in the recumbent position Before

the erect posture is assumed a pad and bandage or a special belt must be so arranged as to exert pressure below the liver margin and some such device must be worn for at least a year after the operation

Results—The mortality of these operations has not been high and the results have been good so far as the restoration of the liver to its proper position is concerned but the amount of relief to the symptoms is often not so great as expected

Operations for Injury

Injuries to the liver may be associated with a parietal wound or may be entirely closed The former type is often the result of gunshot wounds or stabs In civilized countries the closed injuries are the commonest It is important to remember that pathological conditions such as fatty degeneration and venous congestion predispose to rupture These injuries are often associated with damage to other parts especially the lower ribs the diaphragm the lung and pleura or the right kidney or more rarely one of the hollow viscera Sometimes the injury is entirely beneath the capsule

Indications—In compound injuries including the gunshot wounds and stabs met with in civil life the surgeon must always operate In closed injuries the indications for interference are the severity and duration of the shock evidences of increasing hæmorrhage and persistent rigidity The surgeon must not be misled by a slow pulse which is sometimes present even with severe lacerations It is better to operate early than to leave the case in doubt because in these injuries a low grade infection is apt to occur and the records show that the earlier the operation the better the results In subscapular injuries the shock and signs of hæmorrhage may not be extreme but secondary rupture into the peritoneum or bile ducts or infection are apt to supervene and it is in these cases that liver embolism especially occurs The rule must therefore be to operate when in doubt

Preparatory treatment—It is a mistake to hurry patients suffering from abdominal injuries straight to the operating theatre Time should be taken to allow them to get over the primary shock and to endeavour to make a diagnosis of the organ involved and the type of injury In this condition the bleeding is often partially controlled by the abdominal rigidity and may become furious as soon as the abdomen is opened It is therefore very important that everything should be in readiness before the operation is begun This is one of the conditions in which blood transfusion is very likely to be required and the surgeon should be prepared to have it carried out in the course of the operation (*See* p 590) The blood from the peritoneal cavity may be collected filtered through gauze soaked in citrate solution and used for the transfusion The preliminary use of morphia is valuable but it must not be given sooner than half an hour before operation lest it tend to increase hæmorrhage by decreasing the guardian rigidity If there is much distension a stomach tube may

be passed for distension is a great handicap in operating on the upper abdomen and it is particularly apt to be found in the unprepared patient For the same reason a rectal tube may be useful

Technique —If the patient does not present signs of alarming and increasing hæmorrhage and the rigidity is very marked it is well worth while spending time to inject the abdominal wall with novocain or percaine in 1 per cent solution as in the method of anoci association (Crile) The skin muscles and extraperitoneal tissues must all be thoroughly infiltrated The relaxation induced is a valuable help especially if there is difficulty in exposing the tear The steps of the operation are —

1 Rapidly determine the site of the injury
2 Temporarily arrest hæmorrhage
3 Expose the tear
4 Deal with the tear by suture or gauze packing or both
5 Deal with associated injuries
6 Attend to the peritoneal toilet
7 Close the abdominal incision

The abdomen should be opened in the middle line by an incision which extends from the highest point of the costal angle to the umbilicus On first opening the belly there will probably be a gush of blood but this is only what has collected in the peritoneal cavity and is to be disregarded and the surgeon must rapidly discover by palpation the source of the hæmorrhage Having determined that the liver is the organ injured he must take steps for the temporary arrest of the hæmorrhage The method of Hogarth Pringle* may be tried This consists of manual compression of the structures in the edge of the gastro hepatic omentum If this plan does not succeed gauze must be thrust into the tear or about it while clots in the neighbourhood are rapidly cleared away so that the exact extent of the injury can be determined At this stage the reverse Trendelenburg position and elevation of the loin may be of great assistance

The next step is to deal with the tear and the method to be employed depends largely on its accessibility for sometimes it can be felt but cannot be exposed Large nearly separated fragments of liver tissue (it may be a considerable part of a lobe) are best completely removed as necrosis and sepsis are likely to follow If the gall bladder is torn from its attachments it should be similarly dealt with Any tear which can be exposed sufficiently for the purpose should be sutured the most inaccessible part usually posterior being dealt with first The sutures should be of No 3 catgut and interrupted A large round bodied needle is used and ample bites must be taken as there is a great tendency for the sutures to cut through The ends of the first stitch are left long and held to effect traction until the next stitch has been tied after which they can be cut short In this way hæmorrhage is diminished A very ragged tear, especially if there is any question

* Notes on the Arrest of Hepatic Hæmorrhage due to Trauma " *Ann Surg* Oct 1908 xlviii 541

of conveyed infection as in gunshot wounds can sometimes be cleanly excised and the edges brought into good position If the wound cannot be completely sutured as much as possible should be dealt with in this way and the remainder treated by packing The gauze employed should either be soaked in 1 in 1 000 perchloride of mercury, or should be dry and well dusted with sterilized boracic acid powder It is not wise to rely on a merely aseptic pack The gauze may have to be held in position by one or more catgut stitches tied over it, or by another pack pressing the gauze filled tear up against the diaphragm or parietes The neighbouring viscera should be protected from the gauze by strands of rubber tissue Another plan is to pack the omentum into the wound in the liver or to stitch that structure over a large superficial laceration When the tear has been dealt with associated injuries must receive attention special care being taken not to miss a laceration of any of the hollow viscera

The final stage in the operation is the toilet of the peritoneum Large clots in the vicinity and any fragments of liver should be removed, but it is not necessary to attempt to clear all the blood out of the peritoneal cavity, and irrigation is better avoided A track to the surface must always be provided by a rubber tissue drain or a soft split tube, as there may be leakage of bile If the patient is very ill too much time should not be spent on the closure of the parietal wound but three or four through and-through silkworm gut sutures must always be inserted

Lacerations which involve the hilum are particularly serious as the larger vessels or bile-ducts are apt to be torn across If as often happens, the patient is *in extremis*, the most the surgeon can do is rapidly to clear away clots and apply large clamps to the bleeding vessels, the handles of the clamps being brought out of the wound If the condition permits, the parts may be exposed and examined after the vessels have been temporarily clamped The clamp being used as a tractor, the parts in its grasp are gently drawn towards the surface for examination In this way a tear in the portal vein may be exposed and sutured, or perhaps an injured bile-duct repaired In any event, it can at least be arranged that only so much of the vessel is clamped as is necessary to stop hæmorrhage

Gunshot wounds and stabs in civil life should always be explored, because of the likelihood of associated injuries and because exploration gives an opportunity of anticipating sepsis The entrance wound must be excised, but it will generally be necessary to open the peritoneal cavity by a more conveniently placed incision

Subcapsular injuries —If this type is found, the capsule over it should be divided liver debris and clots removed, and the rent dealt with by suture, or as already described

Late interference in liver wounds —Operative interference may be considered necessary after a delay of some days In these circumstances, if there is no active hæmorrhage, it is wisest to be content to

remove debris and clots and to provide drainage Unless for some special reason secondary suture should not be attempted

INJURIES TO THE GALL BLADDER AND BILE DUCTS

These are usually associated with injuries of the liver but may occur independently The usual sites are shown in Fig 401 If free bile is found on exploration of the peritoneal cavity the gall bladder and ducts must be carefully inspected and the complete extent of the damage determined before the obvious injury is repaired When the gall bladder is injured the tear can be sewn up or used for drainage or the viscus can be removed Complete severance of the cystic duct is best dealt with by cholecystectomy An attempt must always be made to repair the deeper ducts The ends are apt to retract and be difficult to find The aim should be end to-end apposition after freshening the torn margins External drainage must be provided in every case and is all that can be done if the torn duct cannot be located Subsequent management is dealt with on p 832

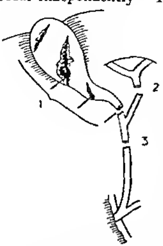


Fig 401 Injuries to the gall bladder and ducts

In 1 cholecys ectomy is indica ed in 2 and 3 the duct ough o be repaired

After treatment —Shock and the effects of hæmorrhage must be dealt with and these may require the transfusion of blood or glucose saline

When to remove the gauze —Liver tissue does not repair rapidly and therefore no attempt should be made to remove gauze packed into a rent for the purpose of arresting hæmorrhage sooner than the eighth day As long as fourteen days may elapse before it can be removed without running the risk of restarting bleeding The gau e should first be loosened gently by pulling on the edges and at the least sign of hæmorrhage the process must be stopped and forty-eight hours allowed to elapse before a further attempt is made

Complications —A mild but insidious form of *sepsis* frequently occurs It may clear up in a week or so or be associated with a fatty change in the liver which often goes on to a fatal termination as one of the forms of Liver Death *Secondary hæmorrhage* is not uncommon from the seventh to the twenty first day If at all serious no time should be lost in exploring the wound under anæsthesia It is to be treated by clearing out all clots and debris from the gauze tract with a sharp spoon used gently The area should then be packed with strands of dry gauze soaked in turpentine all excess being first squeezed out and care being taken to protect the surrounding skin from the irritation of the chemical Horse serum may be used

in the same way *Biliary fistula*, if from the liver substance, will heal spontaneously, though it may take a long time, if the larger ducts have been injured secondary operative interference may be required If bile is passing with the fæces, there is a fair probability of spontaneous healing, even after many months

Results.—Statistics on the results of operation for injuries of the liver are very difficult to compile because of the frequent association of other injuries, and because, as a rule fatal cases are not reported These accidents are extremely dangerous and when they are severe enough to demand operation the mortality is probably between 75 and 85 per cent Some of the conditions met with are so serious that they are of necessity fatal and no operative interference however prompt, can save life Death usually occurs early, as the result of hæmorrhage or shock, later, it is frequently due to sepsis and its consequences In civil life closed ruptures have proved more serious than gunshot wounds and stabs

LIVER ABSCESS

There are two principal varieties of liver abscess (1) as a complication of amœbic dysentery usually called 'Tropical Abscess (2) following some other intra abdominal infection such as appendicitis

Tropical abscess, due to the *Entamœba histolytica* has rapidly diminished since the almost routine use of emetine in suspected cases However, abscesses due to this cause are still occasionally met with and sometimes in patients who have long left the tropics or who have never been abroad It is in such circumstances that the condition is often for long unsuspected and may be overlooked In the second group, liver abscess following appendicitis may be a sequel to those rare cases of pylephlebitis which recover Among other causes are typhoid infections and cholangitis Suppuration in a hydatid cyst may be indistinguishable from solitary abscess with some other ætiology

Tropical Hepatitis and Abscess

Preliminary treatment and aspiration.—The whole treatment of tropical abscess of the liver has been placed on a new footing since the value of emetine has become appreciated in the treatment of amœbiasis Previous knowledge was largely derived from cases much further advanced than are likely to be met with to day, and the treatment was based on the assumption that the pus of such abscesses was pyogenetic, whereas in the large majority of cases it is sterile These abscesses are commonest in the right lobe, but in about 40 per cent of cases they are multiple There is abundant evidence to show that they can recover spontaneously, and the aim of treatment at the present time is to imitate the processes by which nature brings this about

One essential is to saturate the circulating lymph with emetine, which is inimical to the amœba In some cases this is all that is required and the pus becomes innocuous, and either disappears or

becomes inspissated When further aid is necessary, the tension in the abscess must be relieved so as to encourage an outpouring of emetine-saturated lymph from its walls and to allow of their collapse or contraction This is done by the withdrawal of pus This can be carried out more conveniently and safely by a syringe than by an aspirator A large 20 c c Record with a long needle of wide bore answers very well Several syringefuls may be removed, but only as much as flows easily should be withdrawn at one time The process may have to be repeated, but it is not essential that all the pus should be removed The routine treatment ought therefore to consist of (a) intramuscular injection of emetine hydrochloride, 1 gr daily for ten days, (b) removal of pus either with a large exploring syringe or an aspirator The evacuation of pus may be carried out when the case is first seen if there are urgent symptoms due to the size or situation of the abscess, but it is better deferred until a course of emetine has been administered If there is evidence of secondary infection, or the case is not doing well, open incision may be subsequently required, but the preliminary or simultaneous treatment by emetine is necessary in all cases, and aspiration may further help to render subsequent open operation more successful

Aspiration with siphon drainage has been warmly advocated by Sir Leonard Rogers, and it may be an advantage where adequate care in subsequent dressing cannot be secured A special trocar with a flexible sheath is used and is left in the abscess cavity, the tube being allowed to lie in a bottle or basin of antiseptic fluid The instrument is introduced after the situation of the pus has been determined. Only local anæsthesia is necessary, and the trocar can be removed in a few days, the wound healing rapidly

Further indications for treatment.—What follows applies to the treatment of (1) amœbic liver abscess which has not responded to treatment already outlined, and (2) intrahepatic abscesses from other causes

Open incision —In the localization of the abscess, X-ray examination under the fluorescent screen has proved invaluable, and should always be employed to supplement the ordinary clinical signs Before *actually operating, the surgeon must demonstrate the presence of pus* by means of the exploring syringe The needle should be of the size and length used for spinal anæsthesia When there are good grounds for suspecting an abscess, one puncture should be made at the spot at which all the indications point to pus If pus is found, it is better to be prepared to proceed with the operation, either at once or on the next day, further delay being inadvisable If an abscess which has been confidently diagnosed is not found by single puncture, the patient should be put under anæsthesia, so that as many punctures as are necessary can be made, but no puncture should be made without careful consideration of the direction and the depth to which the needle is introduced When the abscess is thus located, the surgeon

can proceed at once with its evacuation Abscesses on the summit of the right lobe of the liver and especially chronic ones may evade discovery by the needle in a remarkable way If there is sound evidence for believing that such an abscess is present and it cannot be found by the needle the abdomen should be opened and if the diagnosis be then confirmed the necessary operation should be performed for the evacuation of the pus either through the same incision or by some other approach

The route to be employed for the treatment of abscess depends on its situation In those rare cases in which the abscess points externally it should be opened in that situation and it will then simply be a question of making an incision for the introduction of a tube

Abdominal route —If the abscess presents downwards it must be opened by an abdominal incision over the site of the swelling This may be vertical either in the middle line or through the rectus muscle If the abscess is on the under surface of the right lobe a transverse incision just below the costal margin is very convenient Should the abscess be found adherent to the parietes the adhesions should not be disturbed and direct opening should be made into the cavity If on the other hand the abscess is not adherent the incision must be so enlarged that an opening can be made directly into its cavity without obliquity The area must then be packed off with gauze and the abscess incised the surgeon taking great care if it is near the border of the liver that he does not thrust any instrument right through that organ to its under surface When the abscess is emptied it may be possible to place one or two catgut sutures between the liver near the margin of the opening and the parietes In any case the tube should be wrapped round with gauze and as far as possible made quite tight in the opening Or gauze should be packed between the incision in the liver and the tube If it has not been possible to suture the liver to the parietes gauze must be carefully packed round the tube to soak up any discharge that may escape by its side and to encourage the formation of adhesions to wall off the drainage track In either event the remainder of the parietal incision is closed by suture and in layers if the condition of the patient admits otherwise by through and through sutures of silkworm gut

The transpleural route —This is the most convenient method of approach for those abscesses which are situated on the upper surface of the liver and which so often raise the dome of the diaphragm The incision must be so placed that its centre will be directly over the abscess so as to avoid reaching the latter by a long oblique track For instance if the abscess is in the posterior part of the liver the incision may cross the posterior axillary line along the 9th or 10th rib in the midaxillary line the 8th or 9th and in the anterior the 7th or 8th In many cases the diaphragm is so high that the lung is pushed out of the way and the two surfaces of the pleura are in close contact or even adherent In any event the surgeon must take great care not to separate the layers of the pleura An incision 3 to 4 in

long is made in the line of the rib which is to be removed, and a rather lesser length of the rib is resected subperiosteally. The periosteum on the deeper surface and the subpleural tissues lying beneath the rib are now incised along the same line without regard to whether the pleura is opened or not One or two sutures of catgut on a rounded full-curve needle are now passed deeply, so as to attach the parietal pleural tissues to the diaphragm. (Fig 402) The ends of the suture are purposely left long and drawn gently towards the surface, so as

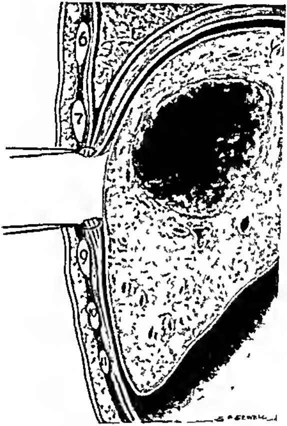


Fig 402 —Transpleural approach to upper surface of liver.

The sutures uniting the costal to the diaphragmatic pleura are purposely shown long Traction on them steadies the diaphragm while this is being incised

to prevent any separation of the pleural surface and to steady the diaphragm while being incised. The incision is now deepened in the same line and the pleura opened along the whole length exposed. The upper pleural surface of the diaphragm will be recognized, as its muscular fibres can be plainly seen through its serous covering If the pleural surfaces now tend to separate, one or two additional sutures of catgut are passed between the parietal tissues and the diaphragm, in order to keep them in contact The latter is then incised for a length of about $1\frac{1}{2}$ in. A vessel will probably be divided and may

require ligature As soon as the under surface is reached pus may be found or there may be inflammatory adhesions or the deeply congested liver may come into view If desired the liver may be palpated or needled or examined in any way In the absence of adhesions a strand of gauze may be gently introduced between the lower cut margin of the diaphragm and the liver so as to discourage escape of pus into the hepatic pouch but this is usually unnecessary as the liver seems to be pressed against the diaphragm either by the tension of the abdominal contents or by cohesion

To open the abscess a pair of sinus forceps is gently thrust into it or a knife may first be required if it is evidently surrounded by a firm capsule as sometimes occurs in the chronic varieties The rubber tube of forefinger size must be in readiness and is introduced into the cavity by the side of the forceps It only requires to be long enough to reach well into the cavity and to project ½ in beyond the skin For better security it should be fixed to both margins of the skin by a traversing silkworm stitch and should also be furnished with a large safety pin As a rule the tube will conveniently occupy the middle of the parietal incision in which case the extremities of the latter should be drawn together by one or two silkworm sutures passed deeply so as to include the structures down to the depth of the rib but the skin must not be closed tightly round the tube

When multiple abscesses are known to exist at the time of the operation it may be possible to break down the walls between them from the cavity first opened or they may be reached by independent incisions or may be treated by aspiration When they are discovered or develop during convalescence the problem of their appropriate treatment will not be altered by the method of treatment of the existing abscess

The extra serous route—Attention was especially drawn to this method by Clairmont of Zurich * It has been further developed by Alton Oehsner and others (1939) and has given good results If the abscess is situated posteriorly even if in the dome of the liver it may be possible to reach it by the posterior extra serous route Local or general anæsthesia may be employed The patient is placed on the left side in the renal position and an incision made along the length of the 12th rib which is excised subperiosteally The pleura crosses the neck of this rib and may be in less danger if the neck is divided instead of disarticulated An incision is then made across the bed of the rib transversely outwards opposite the spine of the first lumbar vertebra and is prolonged backwards to the edge of the erector spinæ (Fig 408) In this way the pleura is avoided When the muscles are divided the perinephric fascia is exposed and is displaced downwards with the kidney The finger now enters the bed of cellular tissue between the upper pole of the kidney and the under surface of the diaphragm By working upwards with the finger in the cellular tissue the region of the abscess may often be reached and opened G dema

* 4 *Lx Ch Scand* 19?? lx 55

indicates that pus is not far away As a rule the abscess can be reached by the finger, but it may be necessary to use an exploring needle followed by sinus forceps If the abscess is high in the liver (Fig 402) a tube used for drainage may be kinked in its rather long course to the level of the 12th rib In these circumstances multiple strands of gauze may be used instead of a tube They are removed one at a time over about a week By the time all the strands are removed the track will be well established and a tube may be introduced if the amount of discharge seems to require it

Operation in two stages—This method can only very seldom be necessary, but if there is evidence that a liver abscess is infected with

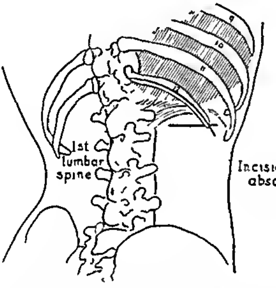


Fig 403 —Extra serous route for posterior sub-phrenic abscess

a virulent strain of pyogenic organisms it may be considered wise to protect the peritoneum or the pleura before it is incised The liver is exposed and the wound leading to the site of the abscess is packed with gauze, a small quantity being placed between the parietes and the surface of the organ to encourage adhesions The second stage should be deferred for as long as four days if possible forty-eight hours being the minimum After the gauze is removed the liver may be incised or punctured and a tube introduced

After-treatment.—The wound should be dressed with gauze soaked in a reliable antiseptic A watery solution of 1 1,000 perchloride of mercury is the best depot antiseptic for this purpose While the discharge is copious the dressings must be frequently changed Though it is desirable to remove the tube as early as possible, it must usually remain for seven to ten days, the time depending on the amount of discharge It may, of course, be shortened during the interval, especially if it tends to be pushed out

If the cavity is unusually slow in healing it may be gently irrigated with quinine (one drachm of quinine bihydrochloride to one pint of sterile water) which is an efficient antiseptic and may do good whatever the type of infection. Most of the complications are due to secondary infection or are associated with the development of further abscesses either in the liver or elsewhere. Empyema is not an infrequent complication in the non-tropical variety. In the amœbic cases emetine must be continued and steps taken to deal with the remaining bowel infection. Whenever possible the patient should remain under observation for some time after the operation, as early relapse sometimes occurs.

Results.—Published statistics give a mortality in tropical abscess of 14.4 per cent. as the result of treatment by emetine and aspiration.* In 1934 Ochsner and De Bakey† reported a mortality rate of 19.5 per cent. for open operation and 4.1 per cent. for conservative treatment. When the combined treatment is better understood and more generally applied this mortality will probably be greatly reduced.

It is fallacious to compare these results with the old statistics of the open operation, many of which date from the time before the value of emetine was understood. In future the open operation will probably only be required in a more serious type of case which has not responded to other methods, and the operative mortality may possibly be higher, but with a proper technique and the necessary care to prevent secondary infection very good results may be anticipated. Recrudescence of liver abscess may occur even years after successful treatment and when the patient has left the tropics.

In abscesses not due to the amœba the condition is much more serious. The mortality, which is high (50 per cent.), depends largely on the causative factor, the organism concerned and the number of abscesses.

Operations for Hydatid

Hydatids may be found in any part of the liver, but much more frequently in the right lobe. Broadly speaking, they may grow mainly upwards towards the dome or mainly downwards towards the abdomen. In parts of the world where this disease is frequent it is often recognized with considerable accuracy, both in its nature and exact position, but in Great Britain it is more often discovered accidentally, and especially when some complication such as suppuration occurs in a cyst of moderate size and first draws attention to its presence. Hydatids are multiple in 60 per cent. of cases, not only in the same organ but in different parts of the body. Before any contemplated operation it is therefore important to make a most careful examination with this possibility in view. The X-ray is a valuable help and will sometimes show both cysts and daughter-cysts.

* Sir Leonard Rogers, *Lancet*, March 11 and 25, 1922, i, 463.
† *American Journal of Digestive Diseases and Nutrition*, 1935, ii, 47.

Indications—As yet there is no method known by which hydatids can be killed *in situ* and as they tend to grow and to disseminate their presence is an indication for treatment But complicated problems may be involved and each case must be considered on its merits Pain or tenderness rapid increase in size the association of pleurisy or jaundice or symptoms suggesting suppuration are all indications for early surgical interference

Choice of operation—Open operation has for the time being superseded all other methods of treatment but where there are multiple hydatids aspiration followed by the injection of 1 per cent formalin may be considered The principle underlying all the operative method is the thorough and complete removal of the parasite (true cyst) without contamination of the surrounding parts The treatment of the adventitious capsule (false cyst) admits of much variation The methods in vogue at the present time are —

1 Removal of parasite filling the cavity with saline and complete closure—Harold Dew
2 Removal of the parasite and drainage of the adventitious capsule—*marsupialization*
3 Removal of the parasite and as much of the adventitious capsule as possible with obliteration of what remains by suture and closure of the abdominal wall without drainage—*capitonnage*
4 Removal or enucleation of the whole cyst together with its adventitious capsule—*excision*

Except as a temporary measure for the relief of urgent distress incision and drainage alone i e without removal of the parasite must never be employed The correct operation suited to each case can only be determined after the cyst has been explored but though excision is ideal marsupialization is probably the best method in the great majority of cases

General Technique—General anæsthesia should be employed as with local there is a definite risk of anaphylatic shock The surgeon must not be hampered by too short incisions and except where suppuration is obvious an ample exposure is necessary There must be no idea of simply cutting rapidly down on to the most prominent part of the swelling and carrying out some dramatic intervention The most direct incision will generally be the right one and it is usually best made over the most prominent part of the swelling The exact incision will depend upon the position of the cyst and this must previously be determined by clinical and radiological investigation In the majority of cases an anterior para median or trans rectus incision answers very well though for smaller cysts the oblique subcostal incision of Kocher may be better When the cyst is situated in the dome of the liver the transpleural or posterior extra-serous approach should be employed (pp 761 763)

The cysts are often multiple and when there are no contra indications

such as suppuration or extensive adhesions, the first step after opening the abdomen should be to palpate both lobes and both surfaces of the liver. As a rule only one cyst should be dealt with at a time, but this partly depends on the size and relative position. In all hydatids, it must never be forgotten that the fluid will almost certainly contain active elements which, if they escape into the peritoneal cavity or soil the wound, may give rise to secondary hydatids with all their attendant possibilities. When the incision has been made down to the hydatid, the first step is to protect the wound and the peritoneal cavity by careful packing with gauze. Professor Dew of Sydney, whose experience in the surgery of hydatid diseases is unrivalled, suggests that the superficial layer of gauze should be black because it is so much easier to detect hydatid membrane or tiny hydatids against this background. When the gauze has been suitably arranged, it should be thoroughly moistened with 2 per cent formalin solution. This will be taken up by the gauze and will act as a sterilizing agent for the infective material. If some of the formalin does soak through the gauze, even into the peritoneal cavity, it does not appear to do much harm and its value certainly outweighs this possible disadvantage. If the hydatid is found lax, a couple of sutures of catgut or silk may be introduced into the adventitia on either side of the proposed incision. These should be used to act as guys to prevent unexpected retraction of the cyst, and also to draw the cyst up into the wound during evacuation. If, on the other hand, the cyst is very tense, it is better to omit the guys until the tension has been reduced by evacuation of some of the contents. While this process is taking place the cyst is kept against the wound by the pressure of the hands of an assistant on the neighbouring abdominal wall. A fine aspiration needle is introduced and enough fluid withdrawn to reduce the tension. The way the fluid escapes is some little guide to the type of hydatid. If it flows freely the cyst is probably univesicular, but if only a small quantity escapes it probably means that there are daughter cysts and this is confirmed if more fluid is withdrawn when the needle is thrust farther. After as much fluid as practicable has escaped an effort is made to kill any free hydatid elements by injecting full strength commercial formalin into the cyst through the same needle. About 5 c.c. for a cyst of a diameter of 10 cm. is a suitable quantity. With the needle still *in situ*, the surgeon waits for from five to ten minutes in the expectation that the formalin will diffuse among the remaining fluid and will help to kill the parasite. After this process of formalization, the hydatid should be incised sufficiently to admit the nozzle of a suction apparatus which should have a bore of about 15 mm. With such an apparatus, the wall of the mother cyst may be sucked into the instrument, or may be drawn into the nozzle and imprisoned and can then be withdrawn. Small daughter cysts will very readily traverse the trochar and will be found in the reservoir. Having removed as much as possible by this means, the surgeon must satisfy himself that all the secondary cysts and the whole of the lining membrane have been withdrawn. A long

sponge handle is a very useful instrument for getting hold of considerable portions of membrane, while smaller pieces or tiny cysts may be entangled in dry gauze used with the sponge handle and gently rotated inside the cyst Whenever possible, the interior of the adventitia should be inspected in order to be sure that the whole of the débris has been removed, for this purpose a strong headlight is very helpful When the surgeon is assured that all the parasites have been removed, the interior should again be swabbed with 2 per cent formalin Redundant adventitia may then safely be cut away but the temptation to try to remove the whole of the ectocyst must be resisted

The stage has now arrived at which the surgeon must decide how to complete the operation that is to say, whether one of the closure methods is to be employed or whether the cavity should be drained If the cyst is obviously infected—which will be indicated not only by the character of the fluid but by its odour—or if it is incompletely emptied or if the fluid contents are stained with bile, then drainage is the only safe method In fact, it may be said that for those who only have to deal with hydatids occasionally it is a sound rule to drain when in doubt The alternative plans available are —

Method 1 —The adventitious cavity is filled with saline, completely closed by suture and returned to the abdomen which is closed without drainage If there is doubt about the secure closure of the adventitia a tube should be brought from the neighbourhood of the site of closure through the parietes to the surface

Method 2 —This may be looked upon as the routine operation and is the one most generally practised by surgeons who have a wide experience of hydatid disease The steps are (1) exposure of the cyst, (2) confirmatory puncture followed by formalinization incision and extra abdominal delivery of the lax part of the cyst, (3) removal of the parasite (4) marsupialization of the adventitia

After the cyst has been emptied as already described, the edges of the incision in the adventitia are fixed with a continuous stitch to the peritoneum and muscle of the abdominal incision, and a thumb-sized rubber drainage-tube is brought from the cavity If there is much oozing of blood the tube may be packed round with gauze In most cases recovery is rapid and complete Should it be necessary to reach the dome of the liver, access is obtained either by the posterior subserous route or the transpleural route after resection of a portion of rib as described in the section on liver abscess (p 761) In order to diminish the undoubted risk of infection of the pleural cavity by hydated fluid Dew advises a two-stage operation in non urgent cases Two or three weeks should be allowed to elapse between the stages The edges of the orifice in the adventitious cyst and the diaphragm should be fixed together by suture and, if the diaphragm is not already attached to the parietes the ends of these sutures should be used to fix it Recovery is equally satisfactory by this method

Method 3 —This method aims at the obliteration of the adventitious

cyst by suture, in order to do away with the necessity for drainage It can only be successfully employed when the cavity is of moderate size, as it is necessary to reach to its depths to introduce the sutures The earlier steps are the same as have just been described *After the thorough removal of the parasite and the swabbing out of the cavity*, as much of the adventitious cyst as can easily be dealt with is cut away The walls of the remaining cavity are then drawn together by a superimposed series of catgut sutures passed around the cavity commencing near the bottom and applied at just such an interval as will ensure apposition of the walls without pocketing Finally the edges of the incision in the liver are drawn together It is always wise to bring a small drainage tube or rubber tissue drain through the abdominal wall from the neighbourhood of the last suture This is merely a safeguard, in case there is a leakage of bile but the drain should not be removed until the abdominal incision is first dressed on the ninth or tenth day

Method 4—Complete excision or enucleation of the unopened hydatid together with its adventitia is certainly an ideal proceeding but it can seldom be safely carried out in actual practice Pedunculated hydatids sometimes lend themselves to this plan but in other circumstances the proceeding is likely to be as dangerous as it is unnecessary However prominent the cyst may be some part of it is almost always deeply situated in the liver substance and its removal in this way entails grave risk of hæmorrhage and of biliary fistula When it can be carried out the area of the liver from which the cyst has been removed must be closed by sutures and if this cannot be done it will have to be in part obliterated and the remainder packed with gauze Except in the simplest cases the operation is not justified

Combined operations—These may be required in certain cases When the cyst is very large it may be possible to cut away a considerable part of the adventitious cyst, the remainder being marsupialized, thus the cavity is diminished and the period of drainage shortened On the other hand the cavity may be so large and extend so far back that a second and posterior opening for drainage is an advantage

Multiple cysts are to be suspected if the cyst does not yield as much fluid as might have been expected from its size or if the main swelling does not diminish after evacuation If possible they should be treated by opening one cyst from another, but in each the parasite must be removed if the operation is to be curative Sometimes each cyst must be dealt with separately, and this may necessitate independent parietal incisions or even repeated operations Very often the treatment of one cyst encourages a second and perhaps unsuspected hydatid to enlarge rapidly and grow forward, demanding another operation soon after the first

Operation in two stages is only required if the cyst is so situated that it appears as though it would be impossible to bring it forward to the abdominal incision even after evacuation When this method must be adopted, an attempt should be made to get some part of the

liver attached to the parietes, and gauze soaked in 2 per cent formalin (with any excess squeezed out) is then packed down in contact with the cyst, so as to make a track from it to the surface A week or ten days later the gauze is removed under anæsthesia and the operation completed

In suppurating cases when the liver is enlarged downwards, a transverse or oblique incision carried back into the right loin is eminently suitable, as it greatly facilitates drainage The posterior subserous exposure may be most suitable for those in the back part of the liver There is often some peritonitis over the cyst, and there may be adhesions but if not the peritoneum must be carefully packed off before the cyst is opened, because it is usually impossible to bring the latter out of the incision when thickened by inflammation In spite of infection it is most important to be sure that the whole of the mother cyst and any daughter-cysts are removed, for suppuration cannot be relied upon to kill them In these and all similar operations a head light may be very useful

In ruptured cyst, immediate laparatomy is the proper course The escaped effusion must be mopped out of the peritoneal cavity and the primary cyst treated by the method which seems best suited to its situation If possible the point of perforation should be made the drainage opening Cases in which *rupture occurs into the viscera* are sometimes cured spontaneously, and hence the surgeon should not hastily interfere When the biliary apparatus is involved, secondary cysts may be impacted in the common duct, and may have to be dealt with like gall stones in the same situation If cysts which have burst into the hollow viscera are opened a fistula may result and may necessitate the separation of the cyst from the viscus in order that the perforations in the latter may be dealt with by suture

Incidental removal of hydatids—Every now and again small hydatids are unexpectedly discovered in the liver in the course of some other operation Their walls are usually calcified If they do not obviously bear a relation to the symptoms for which the operation has been undertaken they are best left alone, unless they are in such a position that they may produce injurious pressure on the bile-ducts, or unless there is definite evidence of activity, as shown by associated trouble They can often be enucleated entire, but this is not always so simple as it looks, and there may be a good deal of hæmorrhage from the bed in which they lie which may have to be dealt with by deep sutures or by gauze packing

After-treatment.—Great care must be taken to avoid secondary infection but this should present no difficulty if reliable antiseptic dressings are applied next the wound and are frequently changed, with proper precautions, as long as the discharge is abundant The tube can usually be safely removed in a week or ten days The amount of discharge must be the guide, but the tube should be dispensed with as soon as possible Suppurating cases may require a longer period

of drainage, but in them the tube must be shortened until it is just sufficiently long to reach into the cavity If the discharge is slow in diminishing, advantage should be taken of gravity, and the surgeon must see that the patient lies for the greater part of each day with the opening dependent In some such cases a second incision may be required to ensure drainage in the most suitable situation

Complications.—Mild anaphylactic symptoms—e g cutaneous eruptions, dyspnœa and asthma like attacks—may appear after some days, but usually disappear spontaneously, without treatment High temperature with or without rigors usually means infection The surgeon must at once make sure that the tube is draining freely for fragments of hydatid membrane may block it Fever which does not abate when free drainage is renewed may be due to sub phrenic abscess, empyema or even cholangitis When it is associated with increasing jaundice, the common duct must usually be drained In such cases the prognosis is grave Persistent sinus may be due to (*a*) a portion of hydatid left behind or regrown, (*b*) failure of the adventitious capsule to contract, (*c*) calcareous plates in the wall of the adventitia (*d*) an unabsorbed suture or even a lost drainage tube, (*e*) a communication with one of the larger bile channels A gentle exploration with forceps may succeed in withdrawing fragments of hydatid membrane Care must be taken to see that the external opening is sufficiently large and patent, and for this purpose a big self retaining catheter is useful An X-ray photograph may be helpful in determining the cause If after three months the sinus remains unhealed, it should be explored under anæsthesia If no cause is found, an independent opening may be considered necessary A mere track may be treated by Beck's bismuth paste, but if there is any communication with the bile-ducts, this method is not without danger

Results.—Apart from the complicated cases, the results are very good MacLaurin, of Sydney, in a series of 70 cases, had 7 deaths, of which 3 occurred among 4 cases operated upon for rupture of the cyst, 2 among 19 cases operated on for suppuration, and 2 cases otherwise complicated That is to say, no simple case died These figures refer to the operation of marsupialization, and reflect the experience of others who employ this method Harold Dew, also of Sydney, points out (1939) that the mortality largely depends on complications In suppurative cases it approaches 20 per cent and with intra pleural or intravisceral rupture it rises to about 50 per cent The published statistics of the treatment by resection show a mortality of only about 9 per cent This low figure is misleading, because the operation can only be done in selected cases and is probably only undertaken by those specially skilled, whereas marsupialization is the operation most commonly employed for every type of case, including every kind of complication, and often by surgeons without any special experience

Late results —In many cases successfully operated upon, further cysts develop This may be due (*a*) to the growth of cysts already

present but not detected at the time of the primary operation, (*b*) to infection from the fluid during operation (*c*) to the re-infection of the patient The development of other hydatids may be delayed for long periods (in some cases twelve years), and it may be that the scoleces have remained latent

Operation for Non-Parasitic Cysts

In several reported cases the cysts have been pedunculated, and it has been possible to excise them safely Those situated in the substance of the liver must be treated as for hydatids Multiple cystic disease of the organ is usually associated with a similar condition in the kidneys and pancreas and is unsuitable for surgical intervention

PARTIAL RESECTION OF THE LIVER

This may be a very simple or a most formidable undertaking depend upon whether the area to be dealt with is pedunculated or otherwise

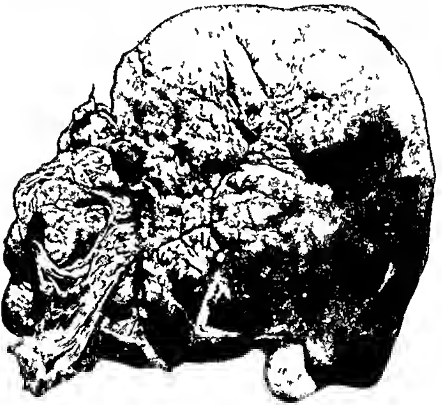


Fig 404 —Portion of liver occupied by large hepatoma

The mass weighing 2 lb 3 oz was successfully excised from a boy of 13 who was alive and well fourteen years later

Though there are many conditions in which resection of the liver may be looked upon as a legitimate surgical undertaking none of these occur frequently, but as they may be met with unexpectedly, it behoves the surgeon to be prepared to undertake this operation at any time

Indications. (1) **Simple tumours**—Those usually found are angiomata or solid adenomata Some of the latter suggest malignant tumours of epithelial type, and are known as hepatomata (Fig 404) Both types of tumour may be quite localized and are often found in a pedunculated area or near the margin of the liver, with a tendency to become pedunculated

(2) **Simple cysts and hydatids**—These are only suitable for resection when definitely pedunculated Sometimes the connection with the liver is narrow and tongue shaped

(3) **Malignant new growths**, such as primary sarcoma, primary carcinoma and some few cases of secondary carcinoma can be resected if a sufficient margin of healthy tissue can be taken away otherwise the operation is valueless

(4) **As part of the operation for excision of malignant gall-bladder**—Some surgeons hold that whenever the gall bladder is removed for cancer a wedge shaped portion of the liver should also be excised Others are content to reserve this excision for cases in which the liver is involved by direct extension The after history of cases of operation for malignant disease of the gall bladder shows that when this condition can be recognized by the naked eye no operative treatment, whatever the type, can be expected to bring about permanent cure, and therefore, unless there are some very special reasons, it is not justifiable to incur the undoubted additional risk which resection of the liver involves

(5) **For direct extension of malignant disease from the stomach or colon**—Usually only a portion of the edge of the liver is invaded, and the surgeon can often deal with this by a comparatively simple extension of the primary operation

(6) **For the removal of Riedel's lobe**—The mere presence of this lobe is not in itself an indication for its excision, but removal may be required when it causes symptoms such as persistent dragging or pain, or when it has become an obsession to the patient The actual decision whether the lobe should be excised can only be made after the abdomen is opened, and the surgeon must then satisfy himself that the anomaly has been the cause of the symptoms complained of, and further, that it can be removed without undue risk In many cases the symptoms are associated with disease in the gall bladder which can be dealt with effectively without interfering with the lobe

(7) **For some granulomata**—Many operations for excision of portions of the liver have been carried out under the supposition that a neoplasm was being dealt with, but subsequent examination has proved that the condition was syphilitic Curiously enough, the gummatous condition has often involved only a limited area, thus further leading to confusion with neoplasm Gummata are usually smaller than malignant nodules, their surface is rounded and not umbilicated, and there is more perihepatitis If the surgeon can recognize the condition as being of this nature at the time of the operation, there is no justification for carrying out excision If real doubt exists, it would be better

to remove a piece for section and to perform a secondary operation if needful The absorption of a localized gumma may be greatly hastened by scooping out its softened centre, and this may safely be done if the patient has already been properly treated for syphilis without result

Choice of operation —The method can only be determined after the abdomen has been opened and the parts have been explored The ideal plan is to remove the growth and to repair the wound in the liver by suture Formerly it was a question of whether the tumour was sufficiently pedunculated to be brought outside the abdomen and the pedicle treated extraperitoneally This method is now seldom, if ever, employed but it should be borne in mind, for it can be used with success if necessary The indications for its use may be (*a*) a well-pedunculated tumour with a very vascular pedicle such as is found in some of the angiomata or (*b*) the inexperience of the operator The tumour is brought outside the abdomen and the pedicle transfixed by two stout needles Wyeth's pins or thick knitting needles will serve the purpose An elastic ligature (such as a piece of fine rubber drainage-tube) is then wound tightly round the pedicle on the proximal side of the needles and the abdominal wall sutured The needles lie on the abdominal wall pads of gauze intervening As a last step, the tumour is cut away either by knife or cautery, and the stump is dressed antiseptically In about a fortnight the pedicle will have become firmly adherent to the parietes and the process of its isolation will be well advanced so that the needles can safely be removed, but it is usually many weeks before the stump shrivels up and heals over

Technique.—The technique presents two problems—(1) the control of hæmorrhage during the operation, (2) the permanent arrest of hæmorrhage and the treatment of the liver wounds

If the tumour is pedunculated, a clamp may be applied to its base The best variety is a stomach clamp with longitudinal grooves and a good bow If such a clamp is slowly applied it may prove efficient without damaging the liver In some cases it may be possible to use an elastic ligature as a tourniquet, and some surgeons pass such a ligature through the liver and tie it on the proximal side of the proposed incision

When the tumour is sessile and the line of incision must penetrate far into the liver substance, the clamp can sometimes be effectually used if the liver is not too thick, or the organ can be held and compressed on either side of the proposed incision by the hands of an assistant As the liver is divided clamps may slip, and the hands of an assistant are often in the way, therefore it is better not to rely on these methods but to pass a series of sutures through the liver substance parallel with the line of the proposed incision and about ½ in from it by the method shown in Fig 405 The sutures of catgut (No 3 or 5) can be passed with a large curved intestinal needle, or right through the liver with a straight needle, and tied as shown

In any event, it is necessary to make the actual incision into the

liver substance slowly so that any bleeding can be arrested as the excision proceeds The branches of the hepatic artery can be caught in forceps and tied Large venous trunks may be surrounded by ligature with a round needle this is tied very gently as there is a risk that it may cut its way out and fail in its purpose After the excision is made apposition of the two cut surfaces suffices to stay most of the bleeding as the blood pressure is so low but it is not always possible to bring the surfaces together even when the excision is in the form of a wedge Whatever method is employed any area that bleeds after the edges have been brought together must be

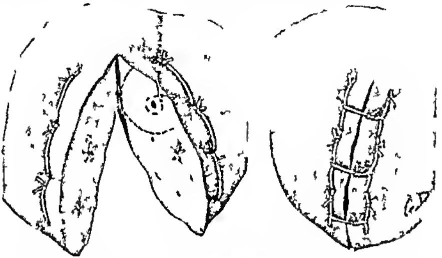


Fig 405 —Diagrammatic representation of method of liver hæmostasis and suture Cf Fig 317 p 658

controlled by an additional suture here and there In some cases the excision has been made with the cautery or with the diathermy knife but these methods are slow and as a means of arresting hæmorrhage very uncertain In dealing with the actual case the various steps required are as follows —

1 Adequate exposure
2 Exploration and decision on the method of removal
3 Temporary control of hæmorrhage
4 The actual excision of the involved area
5 Permanent arrest of hæmorrhage and repair of the liver wound
6 Toilet of the peritoneum and closure of the abdominal incision

The parietal incision will depend on the situation of the tumour and the build of the patient The exposure must be adequate and for most cases some type of vertical incision will suffice but the surgeon must never hesitate to make a cross cut if additional room is required If the tumour is far back on the right lobe then a long oblique incision an inch below the costal margin will be the best It may be possible to obtain much help in the exposure from the reverse Trendelenburg posture the elevation of the lumbar region and the division of the triangular ligament As soon as the abdomen is opened the condition

must be carefully explored to determine the feasibility of removal For this purpose adherent omentum may have to be separated or adhesions to the parietes and the other viscera divided This may be done without hesitation for some of the most favourable cases are associated with such adhesions, and their separation may bring an apparently hopeless condition within the range of safe surgical enterprise The adhesions may be very vascular and unless they can be ligatured are best severed with the diathermy needle If there is any question of malignancy, a careful search must be made, on the one hand for a primary focus and on the other, for further deposits in the

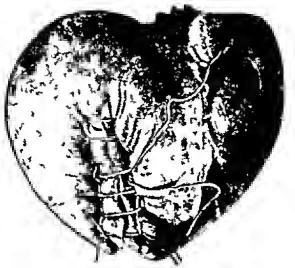


Fig 406 —Drawing of a specimen illustrating method of liver hæmostasis and suture completed

liver (Illustrations of the latter are the not uncommon cases of malignant gall bladder with direct extension to the liver, which could easily be removed by a moderate wedge-shaped excision, but in which a secondary deposit felt elsewhere in the liver renders excision valueless) It is most important to determine the relation of the tumour to the hilum and the incisions that will be necessary for its removal, as this part of the liver must not be encroached upon The gall bladder and cystic duct can of course be removed, if necessary Whenever possible the part to be incised should take the form of a V, but to avoid going too near the hilum it may be necessary to leave the point of the V rounded or rectangular When the part removed is not too large the gap can be brought together by suture, but if this is not possible the apex may be dealt with in this way and the remainder left gaping In order to bring the edges of the V shaped gap together, sutures of strong catgut are passed over the hæmostatic sutures previously introduced (Figs 405 406) The method is difficult to describe but ought to be easily understood from the figures If the sides of the liver wound cannot be approximated, then either the cut

surfaces may be folded on themselves by interrupted sutures, or the gap may be left open when the surgeon is satisfied that the main hæmorrhage has been controlled Every effort should be made to stay oozing, a good deal of which may be due to venous engorgement, which will stop when the liver is allowed to fall back into position Omentum packed into the space and fixed by a suture may help to arrest oozing In spite of great care, it may be necessary to leave in a gauze pack, and in order to exert pressure on the bleeding area, one or two sutures may be passed through the liver on either side, so that the edges of the gap may be drawn together over the gauze It will not be possible to remove the gauze with safety sooner than 10 to 12 days after operation In all cases drainage should be provided lest there be bile leakage

After-treatment.—This is exactly similar to that described for cases of injury to the liver

Results—In recorded cases the immediate mortality, about 15 per cent has not been so high as might be expected, probably because this operation is only essayed by practised surgeons and after most careful consideration The remote results depend on the condition demanding excision Very large portions of the liver can be removed without interfering with the health and well being of the patient (the portion shown in Fig 404 weighed 2 lb 3 oz), and permanent recovery may be expected to follow operation for cysts and simple tumours In malignant disease early recurrence has so far been the rule though with one or two notable exceptions

OPERATIONS FOR CIRRHOSIS OF THE LIVER

The Mayos have carried out splenectomy in some cases of cirrhosis, on the assumption that this condition may depend on metabolic poisons which are elaborated in the spleen With that exception there is no surgical treatment for cirrhosis *per se*, but several plans have been devised for the relief of the consequent ascites Most of the operations are based on that devised and introduced by Drummond and Morison* in England, and independently by Talma and van der Meulen in Holland To Rutherford Morison belongs the credit of establishing the operation on a secure footing and of publishing the first successful case, which was operated upon in 1895 The object of the operation is to *form new vascular communications between the parietal and portal venous systems*, and in that way aid the abdominal circulation and relieve the embarrassed portal vessels An endeavour is made to bring this about by vigorously scrubbing the surface of the liver and spleen and the adjoining parietal peritoneum in the hope of setting up adhesions, and by suturing the omentum to the abdominal wall

Indications.—Drummond and Morison advised that their operation should be reserved for ascites resulting from alcoholic cirrhosis, and

* Brit Med Journ Sept 19 1896 ii 728

they stipulated that the patients selected should be free from cardiac or renal disease and should have withstood several tappings. When these rather rigid indications have been observed the results have been very satisfactory. In other types of ascites, often of undetermined origin, the results have not been so favourable, but there is no reason why the operation should not be tried when other methods have failed. Success is not to be expected, whatever the primary cause, unless the ascites is mechanical and not merely toxic, nor if the patient is already suffering from cholæmic symptoms. For Banti's disease with ascites omentopexy should be combined with splenectomy and has contributed to the not infrequent successes.

Choice of operation.—The after histories of suitable cases treated by the Drummond-Morison operation have been so satisfactory that it remains the method of choice. Attempts have been made to treat ascites by peritoneal drainage into the cellular tissue of the thigh through the femoral opening* or into the subcutaneous tissues of the abdominal wall (Paterson), and these operations have been attended by an encouraging measure of success. They have the advantage of being simpler than omentopexy, and can therefore be carried out with little risk in debilitated subjects. There is the further point that, if not successful, there is nothing to prevent subsequent performance of the complete operation of Drummond and Morison. Direct anastomosis between the portal and systemic veins (Eck's fistula and anastomosis of mesenteric and ovarian or other veins) is not physiologically sound, and though both have been performed with temporary survival, the methods cannot be looked upon as within the realm of legitimate surgical enterprise.

Preparation.—These patients are often bad risks, and a week or two should be spent in preparation. They should be kept in bed so that they get accustomed to lying on their backs. Bowel action should be free, and efforts made to overcome distension. Digitalis, nux vomica or strychnine should be substituted for the accustomed stimulants. The abdomen should be retapped about four days before the intended interference.

Technique.—It is difficult to perform the complete operation properly without a general anæsthetic. The original operation devised by Drummond and Morison comprised three definite steps:

1. An attempt to promote the formation of adhesions between the liver and spleen and the parietes.
2. Fixation of the omentum to the abdominal wall.
3. Drainage of the peritoneal cavity.

The incision is a median one from the ensiform to within an inch or so of the umbilicus. The peritoneum is actually opened to the left of the middle line in order to avoid the round ligament of the liver with its enlarged veins, and the incision stops short of the umbilicus with a view to avoiding injury to the caput medusæ. On opening the peri-

* W. E. Wynter, *Arch. Middx Hosp.*, July 1909, xi, 15 *Clin. Series*; and Sampson Handley, *Brit. Med. Journ.*, April 16, 1910, i, 922.

toneal cavity the first step is to inspect the liver, in order to verify the diagnosis This done, a small independent opening is made just above the pubes, and a Keith's glass tube is introduced into Douglas's pouch, where it remains Any fluid which does not escape in this way is soaked up in mops or removed with the suction apparatus The escape of the fluid and the inspection of the viscera are facilitated by the reversed Trendelenburg position As soon as the fluid is removed, the surfaces of the liver and spleen and the adjoining parietes are roughly scrubbed with gauze with the deliberate object of injuring the endothelial covering, thus encouraging adhesions The omentum is then fixed to the posterior surface of the abdominal wall about 3 in on either side of the midline incision, and again about the same distance below the umbilicus This is best done by silkworm-gut sutures passed through the abdominal wall and tied outside over gauze dossils (Fig 400) The omentum is also caught and sutured to the peritoneum during the closure of the incision, which is to be done with care, as ventral hernia has often been an unpleasant sequel As a last step, the abdomen is carefully strapped and firmly bandaged *from above downwards* in order to keep the parietes and viscera in contact

After-treatment.—From the first, the patient must be kept propped up in bed to encourage all fluid to gravitate to the pelvis The most important consideration is to guard against sepsis Antiseptic measures must be employed, and the gauze around the tube and covering it, as well as the syringe for withdrawing the fluid, should be kept in a solution of perchloride of mercury 1 1,000 The gauze round about the tube will soak up some fluid, and should be changed when soiled The fluid which accumulates in the pelvis must be withdrawn, at first every hour, and subsequently at increasing intervals It soon diminishes so much that only half an ounce or so can be withdrawn by the syringe every four hours When this stage arrives, it is sufficient to apply antiseptic gauze over the mouth of the tube and to change it as often as it becomes soiled The glass tube should be rotated twice daily to prevent omentum getting entangled in the holes and to release any masses of lymph which may block them A rubber tube may be substituted for the glass one about the fourth day, one that will just easily occupy the lumen of the Keith's tube is slipped into the latter, which is then removed After the substitution of the tubes, the patient may be moved in bed more freely All drainage can be dispensed with about the tenth day

The greatest danger is from cholæmia, which may come on about the second to the fourth day, this is guarded against by early and free purgation and by abundance of liquid by the mouth and the intravenous injection of 5 per cent glucose solution or, if response is tardy, blood transfusion As soon as the risk is over, the amount of liquid taken should be diminished as much as possible There is some risk of pulmonary complications, and the patient should be encouraged to take deep breaths and to cough systematically Unless there has been some leakage of fluid through the median incision, this need not

be dressed until the twenty first day when the omental fixation sutures may be removed At the end of a month the patient may leave bed but the upper abdomen should be kept firmly bandaged for some weeks There is usually some re-accumulation of fluid but it is often re absorbed and this process may be encouraged by inunctions of stimulating ointments such as mercury or capsicum though it may be necessary to tap the abdomen once or twice

It is essential that the patient should abstain entirely from all alcoholic liquors if the operation is to be permanently successful

Complications.—Ventral hernia has occurred in several of these cases and may be very troublesome Operations for the radical cure of such hernias have proved dangerous as there is a tendency to cholæmia for some time after the operation The abdominal wall is also unusually vascular as the result of the venous engorgement Some of the male patients have complained very much of inguinal hernia which has usually been present before the operation but has been overshadowed by the more troublesome ascites The fact that such patients are anxious for radical cure is perhaps an evidence of the increasing self respect which results from their restored health For œsophageal varix causing hæmatemesis ligature of the left branch of the coronary has been carried out

Results.—The immediate mortality in suitable selected cases is about 15 per cent and symptomatic cures have been obtained in about 40 per cent of the cases Recurrence of the ascites may follow a return to alcoholic habits but secondary cure may again take place after suitable treatment * Two patients who were rapidly going downhill in spite of careful treatment and repeated tapping are known by me to have been alive and perfectly well thirteen and thirty four years† after operation

Modifications.—The most important is the omission of the drainage tube This much simplifies the after treatment but the fluid often re accumulates at first and the abdomen may have to be tapped several times in the first few weeks or months after the operation Some operators fix the liver edge to the parietes by suture rather than rely on the possible formation of adhesions Occasionally the omentum is shrivelled up and lies close along the colon leaving no apron for fixation to the abdominal wall In these circumstances the transverse colon should be stitched to the parietes Schiassi raised a flap in the abdominal wall and fixed the omentum and spleen into a space made between the posterior surface of the muscles and the peritoneum whereas Mayo introduced a portion of the omentum into a pocket made by separating the posterior sheath of the rectus from its muscle Narath s method aimed at combining subcutaneous drainage with the formation of new vascular channels and for this purpose he introduced the omentum into the subcutaneous tissue of the abdominal wall

*Sinclair White *Brit. Med. Journ.* 1906 i 1757 † *B. & M. S. Journ.* 1945 i 745

MISCELLANEOUS OPERATIONS

Direct incision of the liver may be required to inspect its cut surface, or for removal of a portion for microscopic examination When possible, it is best to select some part of the border of the liver, and the incision should be wedge shaped Hæmorrhage can be controlled by the fingers on either side of the incision while the cut surface is being inspected It must be remembered that the appearance is greatly altered by the consequent anæmia A diathermy knife may be used instead of a scalpel and will usually control the bleeding The liver wound is dealt with as already described

The insertion of radium should only be carried out through an open incision and with the part to be treated fully exposed The containers are passed into the tumour in various directions, attention being especially paid to the periphery The strings from the several tubes are then collected and brought out of the abdominal incision by the shortest route through the lumen of a piece of rubber drainage tubing (*See* Vol II, Radium)

Operative treatment of pylephlebitis.—The acute variety is almost invariably fatal, and the mortality is not likely to be diminished by operation On the other hand, the subacute and chronic varieties are not so fatal as was formerly thought and it is very questionable if operation is likely to improve the recovery-rate There is reason to hope that some of the new sulphanilamide drugs may influence this condition The first essential is the treatment of the focus, and in what follows it is assumed that this has already been done Ligature of the portal vein must be expected to be fatal unless some previous communication has been established between the portal and systemic circulations If operation is decided on, the liver should be exposed and some pus removed from the infected area for the preparation of a vaccine The area should then be covered with gauze, which is left *in situ*, so as to encourage the formation of adhesions and to establish a direct track to the surface The omentum should be fixed to the abdominal wall and to the edges of the parietal incision, as in the operation of omentopexy for ascites (*q v*) Three weeks later, if rigors still occur, the trunk of the portal vein may be tied as it lies in the edge of the gastro-hepatic omentum In some few of these cases a localized abscess ultimately forms and has to be drained

When the focus of infection is in connection with the appendix, it might be more rational and useful to excise the cæcum and lower part of the ileum together with the venous area involved, as in the Jamieson-Dobson operation for malignant disease of the cæcum

INJURIES TO THE PORTAL VEIN

These may occur as the result of external trauma or during operations on the bile-ducts, or a portion of the wall of the vein may be deliberately excised during the removal of tumours Unless prepared for and especially guarded against, the hæmorrhage will be alarming, dark

venous blood welling up in large quantities The first step is to control the hæmorrhage temporarily by immediately thrusting a finger or fingers into the foramen of Winslow and lifting the vein forwards This alone may suffice to stay the hæmorrhage but if not the bleeding point may be compressed between the finger and thumb Another plan is at once to thrust a large artery forceps down to the neighbourhood of the bleeding point taking a grasp of all the structures in the vicinity This may stop the hæmorrhage but in any event it provides a means by which the involved area can be drawn nearer the surface and furnishes a handle for fixation of the deeper structures But this step is only for desperate cases and as a life saving measure because the bile ducts or the duodenum may be seriously crushed Its object is to enable the surgeon to search for and discover the actual site of injury and as soon as that has been done the blindly applied forceps must be removed

The hæmorrhage having been temporarily arrested the next step is to remove the escaped blood and clots and to secure proper exposure The exact site of the injury must now be carefully sought and dealt with A small tear may be caught in forceps and a lateral ligature applied the ligature material should be fine silk or celluloid thread as thin catgut cannot be drawn tightly enough to get a secure hold If this cannot be done long forceps can safely be left *in situ* provided they only occlude the actual hole in the vein i e they must be dis engaged from any other portion of the vein or other structure which they have in their grasp Forceps left on in this way should be loosened at the end of seventy two hours and may be removed four hours later if there is no further bleeding Long lateral tears or deliberate incisions may be successfully sutured by a continuous stitch of thin catgut (6/0 chromic) passed with a fine round needle If the vein is almost divided across the remaining channel must be spared at all costs as the merest trickle of blood reaching the liver is far safer than occlusion When the vein is completely divided it may be possible to repair it by end to-end suture using fine catgut The condition of the patient and the circumstances of the case must determine the course which the surgeon takes in the face of this calamity but the patient must never be allowed to die from unarrested hæmorrhage

Deep bleeding about the hilum of the liver is not always from the portal vein Smaller vessels may be caught and tied or forceps left on and oozing may be treated by gauze packing Some of the most desperate looking accidents of this kind have had a happy ending when the surgeon has tackled the problem courageously while many patients who have been left to their fate might have been saved Im mediate blood transfusion will usually be necessary after the bleeding has been arrested

Injuries to the Arteries

These accidents usually occur during the performance of cholecystec tomy Probably they are mostly due to abnormal position of the vessels It has been shown that in about 46 per cent of subjects some

vessel, either the right hepatic or the cystic, or an accessory cystic artery, passes in front of the common duct or the common hepatic duct (Fig 896, p 750), and is therefore very liable to injury * It is surprising what severe bleeding may come from a divided cystic artery Ligature of either branch of the hepatic artery is very serious and is usually followed by fatal necrosis of the liver Contemplation of this accident only serves to emphasize the possible risks of removal of the gall-bladder, and is a further warning of the need for great care in performing this operation However, in the presence of bleeding, the vessel must be caught, in spite of possible consequences, as the patient cannot be allowed to die of hæmorrhage What has already been said in the previous section applies here and it is most important that only the actual bleeding-point should be occluded The lateral ligature is difficult to apply to an artery, and if this seems indicated because of the risk of occluding the hepatic, it will be safer to leave an artery forceps *in situ*, or to do so in addition to the ligature When artery forceps are left on important vessels their handles should be tied together with strong silk, as they sometimes spring open without interference. Sometimes a silver clip, such as is used in cranial operations, may be applied to the bleeding point

OPERATIONS ON THE GALL-BLADDER AND BILE-DUCTS

Surgical interference may be necessary to deal with infections, to relieve mechanical obstructions, to remove gall stones not complicated by either of the foregoing to deal with other complications or consequences of gall-stones and with new growths of the gall-bladder or ducts, or for the relief of certain diseases of the pancreas

General indications for operative interference.—Infection may or may not be associated with gall stones, and may be either acute or chronic Acute infections, such as occur in some cases of typhoid or paratyphoid fever, may rapidly subside, and all urgency disappear, yet operation may be the wisest course because so frequently the infection becomes chronic and remains a focus for systemic absorption, or gall stones subsequently develop, or the patient becomes a typhoid carrier Either in the foregoing circumstances or when infection is a complication of gall stones, the following are definite indications for operation right-sided peritonitis spreading from the gall-bladder region, recurrent rigors with persistent tenderness over the gall-bladder, distension of the gall-bladder, with pyrexia, persistent tenderness over the gall-bladder quite apart from its enlargement or the degree of pyrexia In other cases there may be symptoms and signs suggesting pancreatitis, and these, of course, indicate early operation

Mechanical obstructions are most commonly caused by the impaction of a calculus in the neck of the gall-bladder, the cystic duct, or the

* E R Flint *Brit Journ Surg*, April, 1923 x 509

common bile duct In either case, the onset will probably be attended by an attack of colic, and this may be followed, on the one hand, by a distended gall-bladder or, on the other hand, by jaundice With a history of gall stone attacks, the discovery of a distended viscus is a sufficient indication for operation, but it must be sought for just after the severity of the attack has subsided, which is the best time to make the diagnosis It is true that such a distended gall bladder frequently empties itself, either because the stone passes on or is released, or because the organ becomes adherent and leaks into one of the neighbouring viscera This event allows the fluid contents and sometimes the calculi to escape, but more commonly the latter remain, though the presence of the communication with the bowel acts as a safety valve and relieves all symptoms In these circumstances, the gall bladder may slowly contract on the stone and at some period remote from the attack cause it to erode into the intestine, where it may be the cause of obstruction of the bowel Jaundice due to gall stones is a comparatively late complication, and one that would rarely occur if the earlier symptoms of gall stone were more frequently recognized as indications for surgical treatment Intermittent or steadily deepening jaundice are both indications for interference

Operation in the absence of infection or mechanical obstruction—The symptoms due to gall stones can be relieved in various ways, but there is no known method of medical treatment which will cause them to be dissolved or voided with certainty, and the only means of cure is by operation In some cases all the calculi safely traverse the ducts or pass through internal fistulæ into the gastro intestinal tract, but there is no assured means (except perhaps occasionally the X ray findings) of ascertaining whether or not this has taken place No interval of freedom from symptoms is enough to signify that the stones are gone, for they may give trouble again after many years There is further, the ever present risk of the onset of some complication Operation in simple cases carries a mortality of about 2 per cent , but in the presence of complications this rapidly mounts to about 10 per cent In quite a number of cases cancer ultimately develops in gall bladders which have for long harboured calculi

It should be realized that whenever the biliary tract is diseased there is probably some disturbance of liver function, so that the choice of the best time to operate and the preparation of the patient are important matters

The best time to operate.—Before any operation on the gall-bladder or ducts, some preparatory treatment is a great advantage There are, of course, certain cases of gall bladder disease, such as phlegmonous cholecystitis and perforations which must be operated upon as emergencies It is not wise to operate during an attack of colic, nor is there any special reason for doing so, for there is very little risk of urgent complications, and pain can be relieved temporarily by other means Symptoms and signs of infection may dictate the time for

operation, but whenever possible it should only be done in an interval In the jaundiced case the surgeon should stay his hand in the hope that the jaundice may disappear or lessen and in order that the very necessary measures for diminishing the tendency to hæmorrhage may be taken If the condition of the patient is improving, it is safer to defer interference until bile is finding its way into the bowel In deciding the very difficult question of how long it may be wise to wait for an attack to pass off, the history and progress of previous attacks may be a useful guide

Preparation.—The necessity for the special preparation of patients about to undergo operations on the biliary tract has been recognized as important since the rôle of the liver in general well-being has been better appreciated and still more since it has been realized that in nearly all conditions calling for surgical intervention both the liver and pancreatic functions are deranged in some degree Unfortunately, there is no simple test for liver function which will give a reliable indication of those minor changes which may be so important

No special preparatory treatment is necessary for patients who ordinarily enjoy good health respond satisfactorily to their environment and make quick and complete recoveries from their attacks of biliary disability Though no special pre operative treatment may be necessary, it is none the less unwise to take these patients off the street, so to speak, and carry out an important abdominal operation Even the mildest cases are better for a couple of days spent in hospital and probably in bed Where there is no urgency very stout people, or those who are merely bulky and indolent, can usually be got into a better condition for operation by a delay of two or three weeks during which time they are ordered a reasonable dietetic regimen, moderation in the use of alcohol and tobacco, and regular walking exercise The hygiene of the mouth and the treatment of chronic bronchial infections should also receive attention In all patients admitted to hospital it is necessary to overlook the systems generally and especially to be assured that the excretory apparatus is doing its work efficiently Quite often, those just recovering from gall-stone attacks are also suffering from the effects of morphia and the disabilities due to that drug should be overcome *Special preparation is imperative when* liver or renal function appears poor, either because of the patient s tardy recovery after an attack of biliary illness or from the results of laboratory investigations Even in the absence of jaundice, such patients tend to be lethargic, there is often much wasting, they are dehydrated and generally chilly, and should certainly be under treatment in hospital for at least a week before any interference Confinement to bed is essential and this alone does much good, especially in warm, comfortable circumstances with a restful environment The bowels should be really well moved and the urinary output must be kept up to normal or increased, and for this purpose patients should be encouraged to take bland fluids in abundance—several pints in 24 hours Nothing is better than water, though the patient may be

encouraged to take it more readily if it is flavoured with lemon or disguised as weak tea These patients should also take a high carbo hydrate diet rich in vitamins If they do not readily respond to this régime glucose should be freely administered either by the mouth or intravenously A total of 3 to 6 oz (100 to 200 g) should be given daily in one form or another Anæmia should be treated and the patients should have blood transfusions when necessary If there is gastric distension or the patient is at all nauseated it is well to use a small stomach tube not so much to draw off any residue as to accustom the patient to this treatment as it may be invaluable during the immediate post operative period If there is any remaining eleva tion of temperature or if fever has played a part in the illness then hexamine in 7 gr doses three times a day should be administered as a biliary antiseptic Any disabling condition associated with the heart or the lungs or with metabolism such as diabetes must be treated in order that the operation may be carried out under the best possible auspices

In the presence of *jaundice* further preparation is required as there is great risk of post operative hæmorrhage or failure of liver function These risks are belittled by some surgeons while others have found that hæmorrhage has been the cause of death in about 16 per cent of their cases Some indication of the risk of hæmorrhage can be gathered from the ordinary clinical examination of the patient for there may be petechiæ or spontaneous subcutaneous hæmorrhages or even bleeding from any scratched surface The laboratory evidence of increased bleeding time and coagulation time are also helpful while the estimation of the blood prothrombin is of the greatest value and indicates those jaundiced patients in whom hæmorrhage will probably occur (Prothrombin estimation is usually made by the method of Quick) Certain measures to diminish this risk have already proved their value and in consequence the mortality of operations in jaundiced patients has been much reduced during the last few years Of the measures which have already been mentioned the administration of fluids and glucose are especially important

Since it is usually necessary to administer a considerable amount of the fluid required by the intravenous route it is essential to keep records of the intake and output so that a proper balance may be established as there is a risk of water logging of the tissues which may be indicated by subcutaneous or pulmonary œdema It is also essential that intravenous administration should be at such a rate that the con stituents can be assimilated Two hours for each 200 c c is probably about the optimum speed If the circulation is good it may sometimes be more convenient to administer extra fluid per rectum In cases with well-developed jaundice 2 000 c c of 5 per cent glucose in normal saline should be administered intravenously in addition to what can be taken by mouth Calcium is of proved value for directly influencing the hæmorrhagic tendency For this purpose 5 c c of a 10 per cent solution of calcium chloride is injected intravenously on each of the

three days preceding that fixed for operation. Great care must be taken not to allow the calcium solution to escape outside the vein, as a troublesome cellulitis is apt to follow. Parathormone (0·5–1 c.c. by the intramuscular or intravenous route) helps to maintain the calcium concentration in the blood, and some authorities advise that it should be administered daily until the risk of hæmorrhage is past (about ten days). When there is evidence of a well-established hæmorrhagic tendency preliminary blood transfusion should also be employed Though there appears to be no laboratory proof of marked deficiency of Vitamin C in obstructive jaundice, orange juice has appeared to be a material help in some cases.

I am fully convinced that these measures are valuable and have contributed to much improved results in my own cases. Certain additional measures, based on accumulating knowledge of the factors which activate prothrombin, have recently been advocated. Patients with obstructive jaundice who are liable to excessive bleeding have low prothrombin levels. The maintenance of normal blood prothrombin appears to depend on the presence in the tissues of adequate quantities of Vitamin K, which is absorbed from the intestine only in the presence of bile salts. In obstructive jaundice, where the bile salts are diminished or absent from the intestine, Vitamin K is imperfectly absorbed or utilized. The hypoprothrombinæmia may be corrected before operation by giving bile salts and Vitamin K by the mouth, or Vitamin K alône may be administered by intramuscular injection. There are several preparations of these substances on the market, but as yet they are only on trial, and in the present state of our knowledge it does not seem wise to advocate any one product. A substance closely resembling Vitamin K (" Kopilon ") has been synthesized and is said rapidly to restore plasma prothrombin to normal when given intravenously. It may be used as a pre-operative preparation. In cases complicated by vomiting, or in patients already bleeding, this preparation may be used in preference to oral bile salts and Vitamin K. In similar circumstances it has also been suggested that Vitamin K (in a preparation known as " Klotogen " and bile salts in the form of " Bilein ") dissolved in 250 to 500 c.c. of water should be given by duodenal tube. Where the prothrombin value remains low, this treatment should be used for three or four days both before and after operation. But whatever steps are taken by way of preparation, they cannot excuse any lack of care in the selection of the time to operate, and the need for precision in carrying out the operation and after-treatment. Gentleness is essential, and every bleeding point that can be caught must be ligatured and the incision must be carefully sutured in order to diminish the risks of hæmorrhage into it.

The local preparation of the operation area is a matter for the predilection of the individual operator, and it is only necessary to offer a warning against over-preparation, which may defeat its object and be wearisome to the patient.

For *anæsthesia* chloroform must be avoided and the gas, oxygen,

ether sequence will usually be the method of choice For patients who are jaundiced and in very bad condition spinal anæsthesia offers some advantage in that possible toxic effects are reduced to the minimum

The operations which may be required are—

- CHOLECYSTOSTOMY —The gall bladder is opened its contents removed and its interior drained on to the surface of the body
- CHOLECYSTENDYSIS —After removal of its contents the gall bladder is completely closed by suture and returned to the abdomen without drainage (The use of this term instead of cholecystotomy avoids the confusion which is apt to arise when words so similar as cholecystotomy and cholecystostomy are employed)
- CHOLECYSTECTOMY —The gall bladder with its contents is completely removed
- CHOLEDOCHOTOMY —Stones are removed from the common duct with or without drainage

Sometimes other procedures are required which do not involve any separate principle or special technique and which are really only extensions of one or other of the above measures and are therefore better unencumbered with special names The operation of lithotripsy —crushing calculi *in situ*—is entirely different in principle from the others mentioned It is scarcely ever used at the present day except as a means of dealing with the soft pigment calculi which may be found when splenectomy is performed in acholuric jaundice Combined operations are sometimes necessary when stones are present in the great ducts as well as the gall bladder Although the clinical history and to a lesser degree the physical signs will give some indication of the type of operation likely to be called for this can only be certainly decided after the abdomen is opened and the preliminary examination made

Choice of operation —The question whether or not the gall bladder should be removed as a routine is still unsettled and will remain so until it is possible to review in more detail the continued after history of larger numbers of cases in which the alternative methods of dealing with the gall bladder have been tried This viscus must have some *function* possibly the secretion of a hormone but in the environment in which mankind now exists it is evidently of no great importance or its absence is very well compensated as so many thousands of people are known to be in good health years after its removal Some surgeons predict that in many cases after removal of the gall bladder the functions of the liver will be seriously interfered with as the result of the dilatation of its ducts and the unaccustomed pressure within them and that in a few years there will be an outcrop of cases of hepatitis the result of this operation Though at present there is nothing to support this gloomy outlook it deserves to be considered with respect

The principal reasons advanced in favour of cholecystectomy are as follows —

1 It removes the site in which gall stones usually form

2 It removes the focus in which infection is most likely to persist For these reasons it is the best safeguard against both the recurrence of calculi and the persistence of infection

3 It prevents many cases of biliary fistula and eradicates more efficiently potential as well as actual pathological processes

4 It eliminates the risk of subsequent cancer in the gall bladder

From a technical point of view it is also urged that the immediate convalescence is easier and shorter because it does away with the necessity of prolonged bile drainage and that for the same reason the abdominal scar is stronger It is also said that cholecystectomy implies a more thorough examination of the deeper ducts than is usually carried out as a preliminary to a mere drainage operation but this is an argu ment for extreme care in the conduct of all gall bladder operations rather than a reason for cholecystectomy

Against the operation it is urged that there is grave risk of injury to the deeper ducts with possibly serious consequences and that there is greater risk from hæmorrhage There can be no doubt about these contentions though not many disasters from hæmorrhage and from injury to the ducts have been recorded But these accidents are largely due to the fact that the difficulties and dangers have not been properly understood They are strong arguments for the proper selection of cases and for greater care in performing the operation but they need not deter the serious surgeon from carrying out cholecystectomy with increasing frequency for the weight of evidence as judged by the after results is in its favour

Though the proportion of recurrences of calculi is undoubtedly higher after simple drainage it is equally true that many patients after removal of the gall bladder suffer from vague abdominal dis comforts which may be distressing Both sides of the question appeal to the public and as a result of the experiences of their friends some patients insist that the gall bladder should be removed while others are equally anxious that it should not be sacrificed

Positive indications for the operation are (1) A calculus in the cystic duct or neck of the gall bladder so tightly impacted that it cannot be removed without risk of subsequent stricture or obliteration (2) Stricture or obliteration of the cystic duct (3) Small shrivelled gall bladder with much thickened walls (4) When there is any suspicion of early malignant disease of the viscus

Contra indications are (1) Some anomaly of the ducts which may much increase the risk of injury to the common duct (2) Jaundice (3) Uncertainty in diagnosis (4) Great inflammatory thickening obscuring the parts about the neck of the gall bladder (5) Great general vascularity with the risk of severe bleeding from the liver bed which may be difficult to control

Between these two groups of cases there are many in which the decision will depend on the actual conditions, on the state of the patient, and on the experience of the individual operator When in doubt, the surgeon should drain rather than remove the gall-bladder, and it must always be remembered that if necessary the viscus can be excised at a second operation, when the conditions for both patient and operator are perhaps more favourable

Choice of operation after the abdomen has been opened.—(1) Cases without jaundice —(a) *The gall bladder is pathological but does not contain stones, and exploration shows that there is no other sufficient cause to explain the symptoms* —In these cases it is most difficult to arrive at a proper decision It is imperative to remember that in about 5 per cent of cases stones are present in the main ducts though absent from the gall bladder External examination may show adhesions between the gall-bladder and omentum, colon or duodenum, which are very significant if limited to this region but of much less importance if also present in other parts of the abdomen Thickening of the wall of the gall bladder, whether from chronic inflammation or from recent œdema, and enlargement of the glands at its neck, are evidences of gross change originating in the viscus An unusual amount of subserous fat is also looked upon as an evidence of infection If there is doubt, it is much wiser to open the gall-bladder at the fundus in order to inspect its contents and the mucous membrane Thick tenacious bile, bile of varying consistence, or bile with an obvious excess of mucus or with a decided odour, is pathological Or there may be tiny calculi or bile-sand which can be readily seen, though not detected by palpation from without When the mucous membrane is of the well-known "strawberry type," or shows congestion in patches or papillomata, there is probably sufficient evidence of pathological change to justify excision Inability to empty the gall bladder by gentle squeezing suggests that there is some anomaly about the neck or the cystic duct which may explain the symptoms In these circumstances anastomosis of Hartmann's pouch to the common duct has led to permanent relief (Pribram) It is in this class of case that immediate cholangiography may prove to be most useful Cases without stones furnish many of the recurrences after simple drainage and, though the surgeon may hesitate to remove the gall-bladder for what appears to be very limited disease, it is probably often the best course The decision must rest with the individual operator and be dictated by his interpretation of the conditions found in their relation to the clinical symptoms

(b) *The gall bladder contains a single calculus, or multiple calculi, but there is no sign of inflammatory trouble, and there are no stones in the ducts* —In these circumstances the surgeon must be guided by his views on the pathology of gall-stone disease Either operation gives good immediate results, but to remove the gall bladder ensures their greater permanency Unless some of the contra-indications are very definite, excision will probably be best

(*c*) *The gall bladder contains stones and is obviously much altered as the result of chronic infection, or is small, thick walled, and glistening* — Removal is certainly indicated, for these are the very cases in which early malignant disease may be present but without any sign by which it can be recognized by the naked eye

(*d*) *There are stones impacted in the neck of the gall bladder or cystic duct, with great or moderate distension of the gall bladder* —If the distension is recent and due to bile removal of the stones and drainage will be attended by good results and collateral circumstances must decide whether the gall bladder is to be removed Old standing obstructions and hydrops are best treated by cholecystectomy

(*e*) *The gall-bladder contains calculi and is big thick walled, and œdematous from active pyogenetic infection* —Here drainage is undoubtedly the safer proceeding for in these cases the parts about the neck are often difficult to expose, and there may be an alarming amount of hæmorrhage from the liver bed due to the recent inflammation Of course special care must be taken to see that the obstruction in the neck of the viscus has been removed It must be remembered that the gall bladder has remarkable recuperative power, and, further, that it is always possible to perform a cholecystectomy as a secondary operation when the inflammatory mischief has subsided

(*f*) *The gall-bladder is gangrenous, or is the focus of a right sided peritonitis, or is associated with an intraperitoneal abscess* —In these cases only life saving measures are justifiable Drainage must be carried out in the first instance and when there is evidence of infection outside the gall-bladder, drainage from these parts must also be provided When the fundus of the viscus is gangrenous, it alone may be cut away, but even this step may be dispensed with in a patient who is very ill The remarks made under (*e*) apply here but no time should be wasted in vain attempts to remove a firmly impacted stone from the cystic duct The risk to the patient is from infection, and if that is overcome the calculi can be dealt with later Sometimes such a stone loosens during convalescence and is extruded through the drainage-tube

(*g*) *There are many small stones in the gall-bladder, and the patient gives a history of repeated attacks of transient jaundice, but no stones are felt in the common duct* —*It is often impossible to palpate very small* stones in the common duct but with a history of only transient jaundice it probably means that they have passed safely into the duodenum in each attack If the common duct is thickened or œdematous or if the contents, as determined by the exploring needle, are turbid, then the duct should be opened If no stones are found, a thick probe or a Lister's bougie 7/10 to 9/12 should be passed down the duct into the duodenum The gall bladder must be dealt with either by drainage or removal The surgeon must not be disappointed if the patient has an attack of colic during convalescence

(*h*) *The gall bladder is small, shrivelled, and adherent, and there is a history of jaundice, but no stones are found* —In these cases the stone has probably passed in the last attack It is best to remove the gall-

bladder and establish external biliary drainage from the common duct a large probe or a Lister bougie being first passed into the duodenum to ensure the patency of the duct

(2) Cases with established jaundice —(a) *A calculus is plainly felt in the common duct and the gall bladder also contains stones* —To expose the common duct it may be necessary to divide many adhesions and to separate the colon or duodenum from the gall bladder In any event the stone in the duct should first be dealt with though on rare occasions it may be necessary to empty the gall bladder first to facilitate exposure of the duct The supraduodenal part of the duct should be opened first even though it may later be necessary to deal with the stone by some other route The stone in the common duct having been removed the gall bladder should be emptied It is a sound general rule not to remove the gall bladder if there has been an impacted calculus in the common duct

(b) *No stone is felt in the common duct but there are multiple small stones in the gall bladder and there have been previous attacks of jaundice* —The duct must be opened and explored and if no stone is found the large common duct probe or a bougie must be passed into the duodenum

(c) *The gall bladder is small and shrivelled and the common duct is so covered with adhesions and so thick from surrounding inflammatory thickening that it cannot be identified* —An incision should be made in the position of the common duct If calculi can be found and removed well and good but if not the surgeon should be content to establish external bile drainage and to operate at a second sitting if necessary It is in cases of this class that a stone is frequently found to have passed while the inflammatory thickening remained The common duct may often be identified by introducing a fine exploring needle obliquely upwards into its supposed site The withdrawal of bile confirms the position of the duct

(d) *The gall bladder and ducts are nodular and hard* —The condition is almost certainly the result of new growth Nodules in the liver or outlying nodules on the peritoneum are valuable confirmatory signs In these circumstances intervention is of no avail and it is unwise to open the gall bladder even if it contains stones When possible an outlying nodule should be removed for microscopic section and the abdomen should be closed without drainage

(e) *The gall bladder is greatly distended but no stones are present* —The lesion is probably in the head of the pancreas and may be inflammatory or neoplastic If an examination can readily be carried out without separating adhesions and thereby running the risk of producing bleeding a diagnosis of the cause of the obstruction may be made Otherwise the experience of the surgeon must decide whether to be content to make a permanent anastomosis between the gall bladder and the gastro intestinal tract or to establish external bile drainage with a view to a secondary operation

General technique. Number of assistants.—This is entirely a matter of practice. For most operations experienced surgeons will require only one assistant, and more will be an encumbrance. For difficult common-duct cases, or in big, fat subjects, an additional pair of hands tn make traction on the liver or to keep the viscera aside may be very helpful.

Instruments. (Fig. 407.)—These, again, are a matter of choice; the

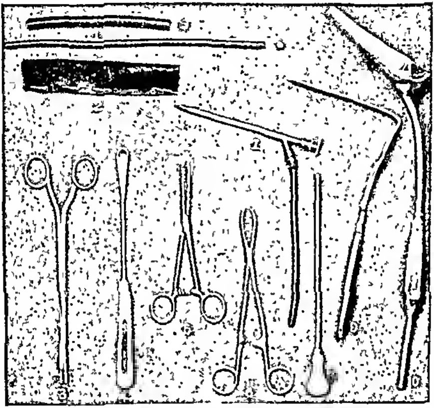


Fig. 407.—Instruments used for operations on the liver and biliary apparatus.

1, Drainage tube with specially thick walls; 2, drain of folded rubber sheeting; 3 Desjardins' forceps for the common duct; 4, gall stone scoop; 5, cholecystectomy forceps; 6, catch forceps; 7, Ochsner trocar; 8, female bladder sound used as probe for common duct; 9, retractor with long malleable blade; 10, receiver with long hollow handle.

fewer special instruments that are used the better. Though it is not generally recommended in upper abdominal incisions, I have found the Balfour self-retaining retractor very satisfactory; the Devine retractor is equally useful but slightly more complicated. A simple retractor with a long blade made of malleable copper, 4 in. by 1 in., is also very useful for cases in which the liver does not lend itself to the method of displacement, or when it is necessary to expose the parts about the hilum. Small volsella-pointed forceps, known in Newcastle-upon-Tyne as "catch forceps," are extremely handy for holding the cut edge of the gall-bladder or the common duct. For cholecystectomy

some type of long artery forceps (7 in) with a slightly curved grasping surface is essential The gall stone scoop of Lawson Tait is the best pattern though it is well to have a smaller size available for exploring the ducts and this should have a malleable handle For extracting stones from the lower end of the common duct the well known Desjardins pattern forceps is the best Any type of trocar and cannula to empty the gall bladder will serve the purpose but it should have an internal diameter of $\frac{3}{16}$ in in order that thick mucus and tenacious bile may traverse its lumen with ease Some form of receptacle is necessary into which the contents of the gall bladder can be emptied a small enamelled tea-cup which can be boiled with the instruments serves this purpose or the instrument illustrated (Fig 407 10) may be used and is convenient and cleanly It consists of a boat shaped container

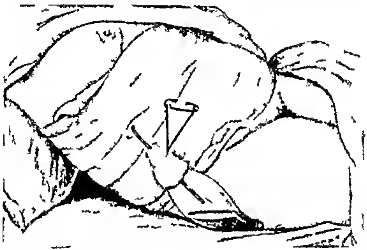


Fig 408 —Bile-drainage into baby s feeding bottle suspended from dressings

mounted on a long hollow stem with a handle The edge of the container is held against the gall bladder and the contents of the latter are emptied into it Fluid with debris and small stones is conducted away through the hollow handle while the bigger stones remain in the boat and can thus be removed without soiling the field A probe made of lead and similar to a female bladder sound with a diameter of $\frac{7}{11}$ in is convenient for passing down the common duct to demonstrate that its orifice into the bowel is free A Lister s bougie size $\frac{7}{10}$ or $\frac{8}{11}$ is also useful for this purpose Needles for suture of the liver must be half curved and of the intestinal pattern and with an eye which will admit No 3 catgut Drainage is best made by rubber tubes For the gall bladder and duct the tubing ought to have thick ($\frac{1}{4}$ in) firm walls so that the lumen is not likely to be obliterated or narrowed by an encircling fixation suture The gall bladder tube should be $\frac{1}{2}$ in in outside diameter (little-finger size) and that for the common duct $\frac{1}{4}$ in in outside diameter (half little-finger size No 10 rubber catheter)

Tubes not intended to go inside the gall bladder or ducts may be of the same size, but thin-walled and soft. Strands of folded rubber sheeting (made of thick dental rubber folded to be 1 in broad and stitched along one edge) are very convenient when it is only necessary to provide a track to the surface or to cover up a raw area on the liver, or to prevent the viscera from becoming adherent to gauze. A baby's feeding-bottle suspended from the bandages is a convenient receptacle when external bile drainage is necessary (Fig 408).

Methods of exposure.—In most cases some type of *vertical incision* will fulfil the requirements. A paramedian incision ½ in to

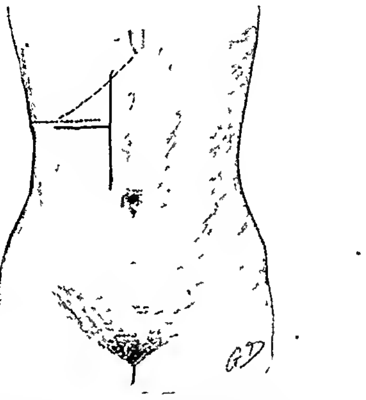


Fig 409.—Incisions for exposure of liver or bile ducts

The vertical incision is commonly employed; the extension upwards and inwards (Mayo Robson) greatly helps *the exposure. A cross-cut through the right rectus may be necessary in difficult operations as for reconstruction* of the bile-ducts, etc. The oblique incision through the rectus is that introduced by Kocher, and the strictly transverse incision (dotted transverse line) was recommended by Rutherford Morison.

the right of the middle line, with displacement of the rectus outwards or a direct incision through the centre of the muscle, is very satisfactory. To get the full benefit of any type of vertical incision, it is essential that it should extend upwards to the costal margin, for it is *this upper part which allows proper rotation* of the liver. In an ordinary case, any type of vertical incision should extend from the costal margin to an inch above the umbilicus (Fig 409). Mayo

Robson secured more room by extending the incision upwards and inwards to the ensiform cartilage and Bevan made a similar extension outwards through the rectus at the lower end of the wound The *oblique incision of Kocher* a finger s breadth below the costal margin also gives an excellent exposure it extends from the ensiform right through the rectus muscle and it may be carried back to the loin or may involve any part of this line depending upon the indications In 1930 Professor Pribram described an incision which takes the same direction as that of Kocher but commences over instead of below the costal margin The rectus is divided and then retracted below the ribs where the transversalis is divided in the same oblique line The incision allows a good exposure and provides considerable insurance against hernia A strictly *transverse incision* as described by Rutherford Morison* (Figs 409 410) is useful in the presence of suppuration In stout subjects it is a good plan to mark out the proposed incision before the patient comes to the table when the parts can be freely palpated and the landmarks defined In any case the incision in the skin and fat is to be 1½ in or in fat subjects even 2 or 3 in longer than that in the muscles (Fig 411)

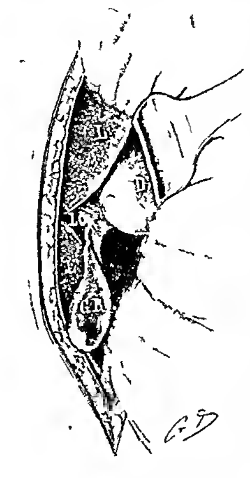


Fig 410 —Parts as exposed in transverse incision of Rutherford Morison

L, Liver LO edge of lesser omentum D duodenum GB gall bladder

With any of these incisions great *additional help in exposure* can be secured by utilizing the normal mobility of the liver The reversed Trendelenburg position encourages the liver to descend toward the incision and facilitates its rotation The latter is brought about by traction on the gall bladder perhaps assisted by the hand passed behind the posterior border of the right lobe The deeper ducts can also be brought much nearer the surface by elevation of the loin (Mayo Robson) This is secured by a bridge on the table operated mechanic

* *Brit Med Journ* Nov 3 1894 ii, 13 —

ally by an inflatable cushion by a sand bag or very simply by the use of the wooden wedges illustrated in Fig 412 * The elevation should not be too high or kept up for longer than necessary as it may cause considerable post operative backache As soon as the peritoneum has been sutured the patient should be allowed to lie flat When the oblique or the transverse incision is employed further exposure is secured by opening out the ilio costal space by pushing the upper part of the trunk and the legs away from the incision i e making the latter the apex of a wedge Too much traction on the liver passing the hand over the liver or gauze packing introduced between that

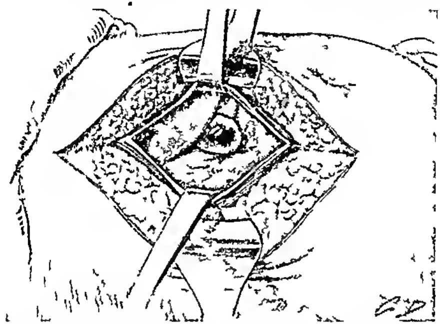


Fig 411 —Exposure of gall bladder in stout subject through vertical rectus incision
(After L[illegible] modified)

organ and the diaphragm should be studiously avoided These methods tend to interfere with the free movement of the diaphragm and encourage post operative pulmonary complications

In any of these incisions and especially the vertical ones through the rectus it is important to spare all motor nerves The latter should never be deliberately divided but should be drawn aside and even after a difficult and perhaps tedious operation they are often found intact when the incision is to be closed

The *choice of incision* is most important and is decided partly by the build of the patient and partly by the pathological conditions For all gall bladder and common-duct conditions without suppuration and in spare subjects the paramedian or the vertical rectus incision gives sufficient room In the obese the oblique incision of Kocher often gives a better exposure but it may have to be prolonged back towards the loin For cases of suppurating gall bladder or those in which an

* Grey Turner *Lancet* 19[illegible]6 i 224

inflammatory mass is felt the transverse incision of Rutherford Morison is very suitable and is admirable for drainage When the diagnosis is in doubt and it may be necessary to examine the appendix or the duodenum and stomach one of the vertical incisions should be selected

The *suture* of these incisions is most important for the prevention of hernia The peritoneum and transversalis should be brought together by a continuous catgut stitch and the outer muscles by two layers of interrupted sutures No 2 or 3 chromic gut being employed according to the bulk of muscle and the tension In all cases a through and through silkworm stitch should be introduced every 3 in Care must

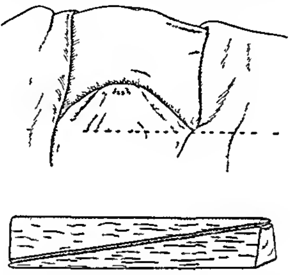


Fig 412 —Elevation of loin (Mayo Robson position) by use of wooden wedges passed from either side after patient is on table

be taken to remove the lumbar support and to appose the edges of the wound as far as possible before completing the suture

The general examination on opening the abdomen —The first step is to confirm the diagnosis of gall bladder mischief The surgeon should next as a routine examine the common and hepatic ducts Though calculi in the ducts can usually be detected by external palpation there are some which evade the best trained fingers The surgeon must therefore be prepared to open the common duct in the absence of palpable calculi in the following circumstances when (*a*) there is a history of recurrent attacks with jaundice (*b*) the duct is found to be thickened (*c*) the lymphatic glands in the vicinity are enlarged, (*d*) exploration with a hypodermic needle shows that the contents are obviously infected or turbid or contain bile sand or are white and limpid In jaundiced cases when stones are felt in the ducts no further examination should be made, as there is always some risk of causing hæmorrhage by even the gentlest manipulations Similarly,

in malignant cases only such examination as is necessary to determine the extent of the disease is justifiable In other cases the pyloric region the duodenum and the head of the pancreas are examined in order The appendix should next be seen and unless very adherent can usually be brought into view by any of the methods of approach which have been described and without any extension of the incision This examination of the appendix is especially important when the gall bladder does not show a degree of pathological mischief consistent with the clinical symptoms The gall bladder must only be dealt

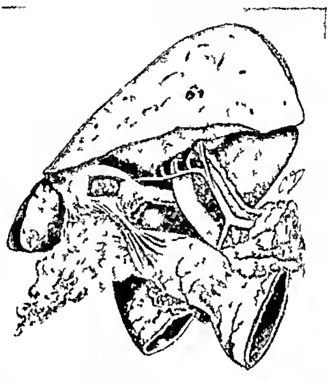


Fig 413 —Showing adhesion of infundibuliform type between duodenum and gall bladder Such adhesions often contain a prolongation from the lumen of the bowel
(After H L Barnard's 'Contributions to Abdominal Surgery')

with in response to the conditions found and not simply because a pre operative diagnosis of gall stones has been made

The next step is to determine what type of interference with the gall bladder and ducts is necessary This may involve preliminary isolation of the gall bladder by separation of adhesions etc this must be done with great care and may be greatly facilitated by the method of gauze stripping If the adhesions are vascular they should be caught in artery forceps before division as even small vessels when they retract cause some subserous bleeding which may obscure the field When the adhesions are to the hollow viscera there is great risk either of opening up some pre-existing communication with the latter—internal

biliary fistula—or of opening into a long-drawn-out portion of the gastro-intestinal tract in an adhesion of the infundibuliform type (Fig 413) It is not always easy to determine the contents and condition of the interior of the gall bladder by external examination and this viscus may have to be opened for diagnostic reasons For this purpose an incision about an inch long should be made in the fundus Enlarged lymphatic glands when examined by palpation may so closely simulate calculi that they may have to be exposed before the decision can be made For suture of the gall bladder or ducts the material should be fine chromic catgut (size 3/0) and the stitches should not perforate the mucous membrane for even catgut sutures have been known to form the nuclei of recurrent calculi (Fig 414)

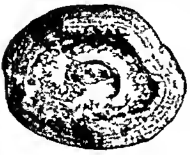


Fig 414—Suture of chromicized catgut forming nucleus of gall stone in a recurrent case

Actual size

(From specimen kindly lent by the late Hamilton Drummond)

Drainage—It is always wise to bring a tube from the neighbourhood of a ligatured or sutured duct as there is sometimes bile leakage which cannot be explained Such tubes should be fixed to the skin rather than to the wall of the duct as in this way the surgeon has absolute control of their removal During the completion of the operation the drains are very apt to slip out of the gall bladder or ducts, and they should be threaded on the long end of a ligature (Fig 421 p 812) or lightly fixed to the cut margin of the duct with a catch forceps (Fig 407 6) until the closure of the incision is completed The final removal of the drainage-tubes depends upon the circumstances of each individual case, but ten days is an average time If drainage for a longer period is necessary the discharge of bile will continue in spite of the fact that the tube is gone As a rule the flow of bile ceases two or three days after removal of the tube but if there is coincident pain or rise of temperature there is probably some unrelieved obstruction or inflammatory trouble Small tubes which are merely left as a safeguard need not be removed until the wound is first dressed Almost the only indication for the use of gauze packing is oozing which cannot be otherwise controlled but it may have to be employed to soak up an excess of bile escaping by the side of a drainage tube in the common duct, or to shut off some infected area Its use should be avoided whenever possible and it should never be packed against sutured ducts or bowel, as the union is very apt to be torn when it is removed Iodoform gauze is not well tolerated by the liver and should not be introduced The hollow viscera should always be protected from contact with gauze by rubber tissue Raw areas on the liver should also be protected to prevent the viscera and especially the stomach, becoming adherent, with possible subsequent kinking and obstruction

General after-treatment.—The patient should be so placed in bed that the operation area is relaxed At first the legs must be kept flexed over a pillow, but after a few hours the patient may be propped up in a half sitting position If there is much pain it is better to give a small dose of morphia (gr ¼) on the night of the operation but after that the surgeon should not hastily give morphia, but should look for and treat the cause of the pain If the patient is shocked, and in all cases of jaundice, water with glucose and soda bicarbonate, and if necessary a little stimulant, must be given per rectum either continuously or intermittently, whichever is the more comfortable If the patient does not respond, the intravenous route should be employed at once As soon as water can be taken by the mouth without discomfort it may be allowed On the day following the operation the patient is often in considerable distress, complaining of tightness across the abdomen and shortness of breath, and the pulse may be much quickened These symptoms are usually at once relieved by loosening the bandage If they persist or recur, or are associated with the eructation of mouthfuls of fluid, it is an indication for the use of the stomach-tube, which often gives immense relief In these circumstances a Ryle's tube may be passed and left *in situ* for twenty-four hours, or even longer At the end of twenty four hours steps should be taken to assist the passage of flatus, either by a glycerine enema or a grain of calomel in four doses (i e one quarter-grain at half-hourly intervals), either of which measures may be assisted by pituitary extract If vomiting persists after the first day or two, it may be due to the irritation of gauze or of tubes about the neck of the gall bladder, and these should be loosened as soon as they have served their purpose Persistent emesis suggests pancreatitis Generally speaking, drainage cases do best when the escape of bile is early and abundant, but the loss of large quantities may have a deleterious effect, as shown by thirst, dryness of the mouth and throat and, later, wasting and signs of hepatic insufficiency The loss should therefore be made up by abundance of fluid by the mouth or, if necessary, per rectum or intravenously In these cases the tube will have to be removed early to encourage the entrance of bile into the bowel In some few critical cases there may have to be bile-feeding, which is carried out by collecting the bile and feeding it into the stomach through a Ryle's tube twice in the twenty-four hours Diluted bile may be administered per rectum, but it is questionable whether it is absorbed

Complications.—These are unusual at the present day, with the more careful selection of the proper time at which to operate, the preparation of the patient, and the improved technique *Hepatic insufficiency* is the greatest risk The patient becomes progressively more drowsy, and lapses into unconsciousness For any patient who is not doing well the most valuable remedy seems to be the intravenous administration of 5 per cent glucose saline, a daily total of about 2,000 c c will probably produce the maximum result The urinary output must be carefully watched and the onset of œdema noted

When the response is not satisfactory transfusion with fresh blood should always be tried Nor should the importance of the old method of purgation be overlooked *Hæmorrhage* may very rarely result from the slipping of a ligature This type of bleeding is only likely to occur in the few hours immediately succeeding the interference Such a catastrophe demands the instant re opening of the abdomen A late type of bleeding in jaundiced patients is much more likely to occur either some forty eight hours after operation or about the tenth day it is usually a progressive oozing into the peritoneal cavity or into the wound more rarely into the bile ducts and bowel A large amount of blood may accumulate in any of these situations When there is no external bleeding it is essential to employ measures which restore the coagulability of the blood and make up for the amount lost while at the same time toxemia is counteracted To restore coagulability vitamin K therapy seems to offer the most promise To make up the volume blood transfusion is best but glucose saline may be used as a substitute until real blood can be obtained Even if bleeding is not of any great amount it is none the less a danger signal and should be met by prompt measures If the hæmorrhage is into the wound some of the skin-sutures should be removed and the site of the oozing may then be packed with gauze soaked in horse serum or if this fails in snake venom (Russell s viper solution of 1 in 10 000) or turpentine while the other measures mentioned are also employed

Escape of bile into the peritoneum—Fatal peritonitis has followed leakage from the divided cystic duct but this should always be prevented by bringing a small tube from the region of the ligatured duct to the surface Sometimes bile escapes from the common duct and finds its way into the lesser sac which it distends A low form of localized peritonitis follows and the patient may become gravely ill This may be suspected when in a common-duct case the general condition is not satisfactory there is sickness the pulse rises and there is an icteric tinge with an epigastric swelling at the end of about a week When the wound is re-opened and drainage of the lesser sac established these cases usually do well

Impaction of fæces is a frequent complication in jaundiced cases

It is not at all uncommon for an isolated attack of severe colic to supervene two to four weeks even after most successful operations This may be due to a small fragment of stone a mass of inspissated bile or a bloodclot traversing the ducts

It should be realized that jaundice if well established is slow to disappear even in cases that are making good progress

Cholecystostomy

Technique—The choice of incision has been discussed The steps of the operation are

1 General exploration
2 Isolation of the gall bladder and protection of peritoneum

3. Evacuation of the contents and re-examination of ducts.
4. Introduction of tube.
5. Toilet and closure of abdominal incision.

On opening the abdomen the surgeon must first carry out the general examination. When the gall-bladder is greatly distended or very tense, it may not be possible to examine it satisfactorily by palpation or to reach the parts about its neck. In these circumstances it should be packed off and aspirated, as a first step. If there are stones in the cystic duct, the surgeon must at this stage assure himself that they can easily be manipulated back into the gall bladder, or the case is one for removal of the viscus.

The next step is the isolation of the gall bladder by gauze. Four swabs are arranged around the fundus, or the latter is passed through a hole in the centre of a large pack in such a way that the margins of the opening fit closely around the gall-bladder. For this purpose the mackintosh swab of Moynihan is very useful. This is the proper stage at which to open the gall bladder, if it has not been previously necessary. It is most cleanly done by first using a trocar and cannula which is thrust into the fundus and draws off the fluid contents; the puncture so made is then enlarged with the scissors to about an inch in length. Any small vessels which spout ought to be caught and tied.

The contents of the gall bladder are removed with a gall stone scoop, followed by the light introduction of a strip of gauze, which serves the double purpose of entangling small stones and of absorbing fluid and preventing soiling by the further escape of contents during the next step. The surgeon then passes his finger and thumb down the outside of the neck of the gall bladder until his finger-tip is in the foramen of Winslow. In this way he reaches the lowest part of the cystic duct and works the fingers gently towards the gall bladder, into which any stones or débris are "milked" back. At this stage there may be considerable difficulty in dislodging a stone which is firmly impacted in the neck of the gall bladder or the first compartment of the cystic duct. This must be released by pressure with the finger and thumb. If necessary the force used may be considerable, but great care must be taken to apply it just over the lower end of the stone, and to ensure that the neck of the gall-bladder is not torn away from its attachments—an accident which would demand its removal. This difficulty in dislodging the stone may be met by incising the neck of the gall bladder with a knife from within; or it may require a direct incision from the outside in the long axis of the duct (*cysticotomy*) or, if small, the stone may only be reached by slitting the gall bladder and duct right down to the site of impaction. There may, further, be a little doubt whether a nodule felt is a stone or a gland, and on this point the surgeon must be satisfied before finally deciding to drain the gall-bladder. When he is assured that the cystic duct is free, the gauze in the gall bladder is removed and the scoop again gently used. Finally, the finger should always be introduced into the viscus to make sure that it is empty, and, if there is any doubt, this examination is com-

bined with a further simultaneous examination of the parts about the neck by the fingers of the other hand working from outside

The tube is now introduced, it should pass about as far as the middle of the viscus The fundus is closed round it by a purse string suture of No 1 catgut, which takes a good hold of the wall of the gall-bladder but does not perforate the mucous membrane If this tucks in the wall satisfactorily, one suture will suffice, but should it not do so, a second may be used, or a couple of interrupted sutures passed at either side of the tube When the gall bladder is very rigid or thickened from œdema it may be impossible to invert it and in these circumstances the opening may be drawn together round the tube by one or two interrupted sutures at either side If the closure round the tube is not accurate the surgeon must use his discretion whether it is necessary to protect the area with gauze or with a strand of rubber tissue which will conduct any leakage to the surface Unless there has been some soiling of the hepatic pouch (Morison s pouch), or some question about the integrity of the neck of the gall bladder, no further drain is necessary In either of the latter events a soft rubber strand had better be brought from the depths of the pouch up by the side of the gall-bladder tube It is best not to attach the fundus of the gall bladder to the parietal peritoneum Even if there is a considerable distance between the incision and the gall bladder, the drainage tube will safely bridge the gap and the surgeon need have no anxiety on this head, provided always that the tube is not removed sooner than a week after operation The drainage tube is brought out by the most direct route—usually through the centre of any vertical incision or the posterior end of the transverse or oblique variety It is attached to the skin by a silkworm stitch, and is then conducted through the dressings to the bottle for drainage (Fig 408, p 794) If prolonged drainage is necessary, it is best to attach the fundus of the gall bladder to the peritoneum and transversalis fascia, and in about fourteen days to substitute a self retaining catheter for the tube When the gall bladder is of the buried type (Fig 415) or is very deeply situated as in fat subjects, it may be well nigh im

Fig 415 —Hour glass gall bladder of hidden type with fundus tightly contracted on single stone

possible to introduce sutures In these circumstances they may safely be omitted if a strand of gauze is packed into the interior of the gall bladder round the tube and is brought out by its side Although this plan appears to be rather slovenly, it has never given cause for anxiety or subsequent dissatisfaction

After-treatment.—The only special point concerns the removal of the tube It should not be taken out sooner than a week, and may be left as much longer as is considered necessary, having regard to the purpose of the interference For instance, if the gall bladder is obviously much infected or if there is longstanding infection of the deeper ducts, or the patient is a typhoid carrier, drainage for several weeks may be required, and should only be terminated after bacteriological examination of the bile After removal of the tube, bile may be discharged externally for a few days, but if there is no obstruction in the deeper ducts this may be expected to cease spontaneously in seven to twenty-one days from the date of the operation If there has been much swelling about the neck of the gall-bladder, as in some of the acute cases the bile may not flow for three or four days after operation, but in the majority it does discharge externally almost at once Failure to do so suggests that either the drainage-tube or the cystic duct is blocked

Cholecystostomy combined with Excision of the Fundus of the Gall-bladder

This may be necessary in cases of gangrene, or where the gall bladder is unusually friable, or of hour-glass form with too narrow an isthmus to permit safe drainage (Fig 415) The fundus must first be separated from the liver to the extent of the proposed removal Some small vessels may have to be caught and tied, or under-run with catgut on a curved needle, and if necessary the bed from which the fundus has been separated may be closed by a couple of sutures Any calculi in the gall bladder are manipulated into the part to be removed, which may then be cut away with scissors without previous clamping, but vessels that spout must be caught and tied The wall of the gall-bladder is now grasped by catch forceps and its remaining contents carefully dealt with, as already described The new fundus may then be closed with a purse string round a tube, or may be diminished by suture up to the point at which the tube emerges If the closure is not very satisfactory, a soft rubber tissue drain is laid over the suture-line and brought out through the parietal incision via the gall bladder bed

Cholecystendysis (Removal of Stones and Immediate Closure of the Gall-Bladder)

At one time this was looked upon as the ideal operation for gall-stones, and was advocated by Kocher * Now that it is recognized that gall-stones which give rise to symptoms are always associated with changes in the wall of the viscus, this method has been superseded

* Text book of Operative Surgery 1911

by drainage or cholecystectomy I sometimes employ it however in cases in which gall stones are discovered in the course of some other operation and there is no evidence that they have produced changes in the walls i e for the incidental removal of gall stones

Technique —If this step is only an extension of some other operation the incision must be so enlarged that the fundus of the gall bladder can be made easily accessible It is isolated by gauze and opened All bleeding points in the incision are caught and tied with very fine catgut The contents are removed special care being taken to determine that the neck and cystic duct are free from calculi The interior is now dried with gauze and the incision in the fundus closed For this purpose catgut is used but the sutures must not perforate the mucous membrane The first stitch is to secure accurate closure and hæmostasis for there must be no bleeding into the cavity The second suture should be a purse string in the peritoneum at least ⅜ in from the first thus turning in a good area at the fundus If the surgeon has the slightest doubt about the patency of the cystic duct or the accuracy of the closure a small tube should be anchored to the fundus and brought through the parietal wound It need not be removed till the first dressing for it does no harm and may at least add to the surgeon s peace of mind

Cholecystectomy

Technique —The steps of this operation are as follows —

1 General exploration
2 Isolation of the gall bladder
3 Exposure of the common cystic and hepatic ducts
4 Isolation and division of the cystic duct
5 Isolation and ligature of the cystic artery
6 Separation of the gall bladder from the liver
7 Double ligature of the cystic duct
8 Treatment of the liver bed
9 Drainage and toilet

The parietal incision must be adequate as every step has to be carried out under the guidance of the eye and it is in this operation that the additional aids to exposure are so necessary and helpful

The first step is to make the thorough examination detailed on p 798

There are two principal methods of removing the gall bladder One commences the separation at the fundus the other deals first with the cystic duct and artery the latter is much the better plan The objection to beginning at the fundus is the difficulty of preventing blood running down and obscuring the more important region of the neck and the undoubted risk that unless special care is taken the hepatic and common ducts may be pulled up in the form of a loop and divided without being recognized (*See* Fig 122 p 813) There is also the further consideration that if some anomaly of the ducts contra indicating excision is discovered when the neck is reached it may be too late to retire gracefully A tense distended gall bladder sometimes

peels off from its bed even on the gentlest handling If it is not desirable to remove such a viscus it may be re attached to the liver after its contents have been dealt with or the method of partial excision may be utilized For the former purpose one or two sutures are passed between such part of the gall bladder as it is necessary to retain and the peritoneal fringe skirting the gall bladder fossa One of the advantages claimed for the operation of cholecystectomy is that the gall bladder with its contents can be removed unopened

Fig 416 —Gall bladder with portion of common duct (shown with glass rod introduced) inadvertently removed during cholecystectomy

thus avoiding any risk from contamination of the field At the same time it must be realized that though this is an ideal plan it is not essential and if necessary the surgeon need have no hesitation in opening the viscus Sometimes the gall bladder is so much distended that it obscures the field and the neck cannot be properly exposed until the viscus has been diminished in size by aspiration In these circumstances the fluid contents may be withdrawn by a trocar which is then removed and gauze clamped over the opening the clamp acting as an efficient handle during the necessary manipulations There is always grave risk of injury to the hepatic or the common duct in the operation (Fig 416) The only way to avoid this calamity is clearly to see the three ducts before the cystic duct is divided

Removal by the method of choice—The first step is to expose the infundibulum This part is commonly obscured by adherent omentum which must be separated or it is adherent to the duodenum which must be gently drawn away This as a rule is easily done by blunt gauze stripping but firmer adhesions may require the use of the scissors The next step is to grasp the infundibulum with a strong pair of curved forceps and to draw it gently towards the surface (Fig 417) This helps to expose the cystic duct and to straighten it It is next necessary to snip through the peritoneal sheath—the hepatico colic fold—which surrounds the cystic duct and artery and com

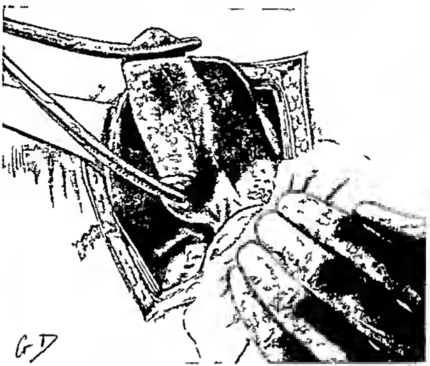


Fig 417 —Cholecystectomy first stage

The fundus is grasped with forceps to be used as a tractor and the infundibulum is drawn aside exposing the hepaticocolic fold and the parts about the neck

monly encloses a considerable quantity of fat As soon as the peritoneum has been divided the scissors must be discarded and the exposure of the ducts completed by blunt dissection with the forceps aided by gauze stripping At this stage it may be found that the hepatic and the common duct are rotated in such a way as to lie over the junction with the cystic duct to which they are adherent but from which they can easily be separated A sharp look out must be kept for abnormal vessels passing towards the gall bladder they must be caught before being divided as bleeding interferes with the clear view that is necessary The dissection is now continued until the three ducts are plainly seen and *in no circumstances must forceps or ligature be applied until all three can be recognized beyond all question* In the majority of

cases not much difficulty will be experienced. Probably the common duct will first come into view, then the cystic, and above the two the hepatic duct can be recognized (Fig. 418). In the conditions which demand this operation the parts around the cystic duct are often thickened from œdema or chronic inflammation, and a good deal of tissue may have to be separated before the duct itself is exposed. When seen it is closely examined, and care must be taken that there is room for the forceps which are next to be applied below

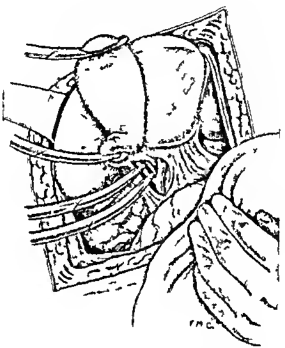


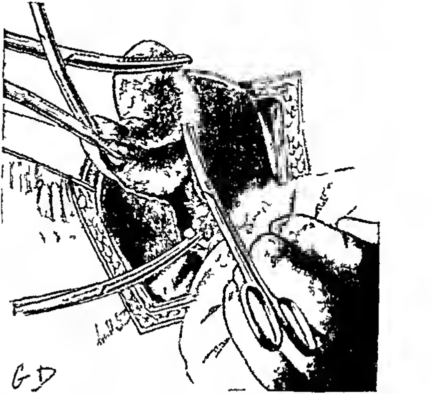
Fig. 418.—Cholecystectomy: second stage.

The three ducts are clearly exposed and the cystic duct has been isolated and caught in forceps ready to be divided between them

the last stone and between it and the junction of the cystic with the common duct. Some surgeons prefer to isolate the duct by blunt dissection with an aneurysm needle and to use this instrument for passing the ligature around the duct. It is extremely important to ensure that no portion of the common duct is unwittingly cut away. In ordinary cases it is not essential to take away the whole of the cystic duct so long as it is divided below any impacted stone or stricture. If necessary the cystic duct may be cut off flush with the common duct, but in that case a tube will have to be passed down into the common duct or placed over the opening in it. The cystic duct should not be divided until it has been clamped or ligatured, as it may retract and may not easily be found again and bile leakage will

be inevitable for a considerable time The duct having been divided the separation with scissors or forceps is continued until the cystic artery is seen above and to the inner side of the duct where it is *caught in forceps* it is best tied and the ligature cut short at once lest it be pulled off in the subsequent manipulations (Fig 419) The gall bladder is then gently drawn upwards away from the ducts

When the viscus has been separated for about a third of the required amount it is left as a handle while the stump of the duct



F g 419 —Cholecystectomy th rd stage

The cystic du has been divided, and also h artery Th gall-bl dder is being separa ed from t bed

is dealt with As a rule this should be ligatured but it may be utilized for drainage or *it may be dilated with a pair of forceps until* it will admit a tube passed into the hepatic duct or the common duct may be opened by slitting the cystic duct right down into it If the duct is to be tied it is safer to apply two ligatures one below the clamp and one to the extremity of the duct which is caught in another artery forceps for that purpose The former ligature is left long at this stage Any bleeding about the stump is now dealt with and the separation of the gall bladder from the liver completed This is usually very easy but may require the aid of the scissors It is necessary however to keep in the proper plane or the liver tissue may be much torn One or two vessels will have to be caught The

bed from which the viscus has been removed may be closed with a suture here and there (Fig 420), or by a continuous stitch if it is surrounded by a sufficient peritoneal fringe, or it may be merely a deep sulcus in the liver, the edges lying together without the aid of sutures Some venous bleeding may occur and be due to passive

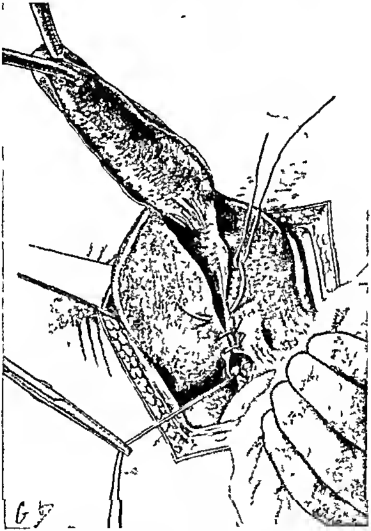


Fig 420 —Cholecystectomy fourth stage

The cystic duct has been ligatured the gall bladder is left attached at the fundus as a tractor while its bed is being closed by interrupted sutures

congestion of the part of the liver withdrawn from the abdomen, if so, it will stop as soon as the liver is allowed to return to its bed In all cases a small soft tube (¼ in in diameter) should be brought from the neighbourhood of the divided duct as a safeguard Occasionally there is bile leakage almost at once, probably the result of some small tear into one of the ducts which has been made during the

process of separation, or to the division of some small accessory duct opening directly into the gall-bladder Leakage several days after operation results from too early absorption of the catgut ligature or from infection Some operators close the abdomen without making provision for bile drainage, but in that case the stump of the cystic duct is very carefully buried by placing peritoneum and cellular tissue about it It is much sounder practice to leave in a small tube The ligature on the cystic duct which has been left long should

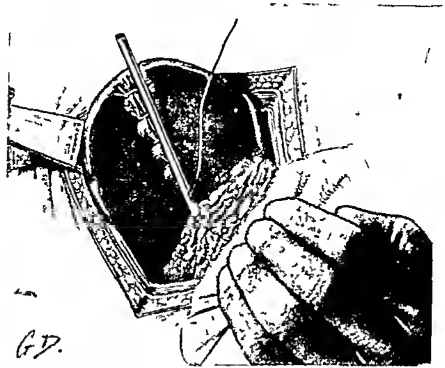


Fig 421 —Cholecystectomy completed

The tube passes down to the cystic duct and is threaded on to the ligature used for the latter The small omentum and neighbouring fat have been drawn into the space between the duodenum and the liver and fixed by one or two points of suture to prevent adhesions between the hollow viscera and the area from which the gall bladder has been removed.

be threaded on a needle and passed through the wall of the drainage tube from its lumen On this the tube is guided down to the proper site and is held there until the packs are removed and the abdomen is about to be closed If it has been impossible to cover in the gall bladder bed or if there is a raw area about the neck of the gall-bladder, this may be protected (i e from adhesion of viscera) by the small omentum and neighbouring fat, which can be drawn over it as shown in Fig 421

Removal of the gall-bladder commencing at the fundus.—This method is forced upon the surgeon in those cases where a very tense gall bladder has only a limited attachment to the liver, which gives way the moment the viscus is handled It may also be expedient

when the gall bladder *has a distinct mesentery* or when it is so small shrivelled and rigid that it can scarcely be manipulated until freed from its bed Whenever this method has to be adopted the one essential is to isolate the cystic duct and to demonstrate its relation to the hepatic and common duct *before* it is divided The temptation is to make traction on the gall bladder and to treat the region of the neck like a pedicle * There is then a great risk of injury to the deeper

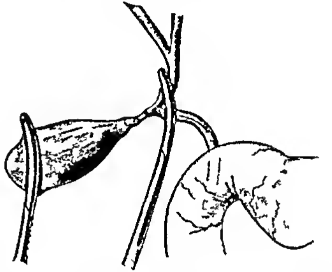


Fig 422 —Illustrating one way in which the common bile duct may be injured during cholecystectomy
(*Modified from Kehr*)

ducts as shown in Fig 422 It is surprising to find how often this accident has happened even in the hands of experienced surgeons Hæmorrhage from the liver bed may be troublesome because the branches of the cystic artery are divided before the main trunk is dealt with it should be controlled by suture or ligature while the gall bladder remains as a convenient handle

After treatment —In the great majority of cases there will be no bile leakage The tube need not be removed until the time of the first dressing at the end of a week Recovery is usually easy and satisfactory and patients are able to leave bed in two or three weeks

Difficulties and complications —These are nearly all connected with injury to the ducts and attention must again be drawn to the anomalies of the cystic duct and to the necessity of identifying by sight all three ducts before the cystic duct is divided The operator should get an assistant to examine the gall bladder as soon as it is removed and if there is any question of injury to the ducts they should be examined at once so that the damage may be repaired while fresh (p 836) Another danger is from hæmorrhage If this occurs either from some uncaught vessel or because a ligature has slipped

* Hans K hr Die Praxis der allgem ge Chir gie in Wort und Bild 19 3

it is necessary to see and to catch the individual vessel Very often this cannot be done at the moment because the field is flooded with blood In these circumstances the surgeon should rapidly apply a large clip to the bleeding area for the purpose of temporarily arresting the hæmorrhage, and this may be used as a tractor by which the parts can be gently drawn towards the surface while the blood is sponged away and the actual vessel is found and separately caught and tied Many accidents are due to the fact that a mass of tissue is hurriedly tied in thoughtless efforts to stop hæmorrhage A still worse pro-

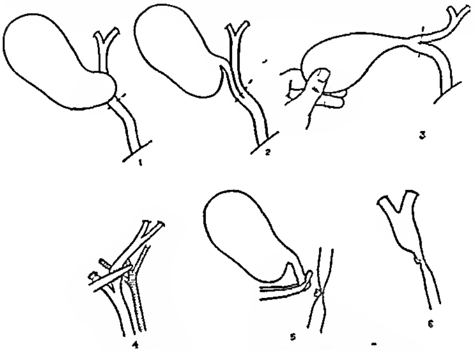


Fig 423 —Some of the various ways in which the common duct may be injured

1 The pouch of Hartmann overlies the junction of the ducts 2. Cystic and common duct run side by side and may be adherent 3 Common duct unusually lax and likely to be drawn up as a loop 4 Injury by artery forceps hastily applied to control unexpected hæmorrhage 5 The stump of the cystic duct is much too short. 6 Stenosis following removal of the acutely inflamed gall bladder the inflammatory process has spread to the common duct and been followed by fibrosis.

ceeding is to pass a needle deeply about unidentified structures which are thus surrounded by a ligature and blindly occluded Sometimes there may be very great difficulty in tying the vessel in the depths of the wound In these circumstances no harm will come from leaving an artery forceps *in situ*, provided its grasp includes only the bleeding vessel Such a forceps should be loosened in forty eight hours and removed a few hours later if there is no further bleeding

Alternative Methods of dealing with the Gall bladder when Complete Formal Excision is not Expedient

These methods are four in number

1 Partial excision

2 Removal of the mucous membrane only—subserous decortication
3 Destruction of mucous membrane by cautery
4 Electro-surgical obliteration

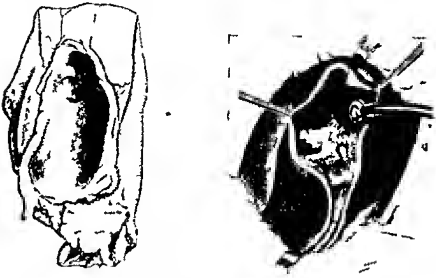
1 **Partial excision.**—This may be limited to the fundus, or to the whole of the gall bladder except its neck The latter plan is to be used when there is special difficulty in exposing the parts about the neck, or when this exposure has disclosed some condition of the ducts contra indicating the usual type of removal If the cystic duct is patent, as shown by the escape of bile or the facility with which a probe can be made to traverse the duct it is not necessary to do anything more than bring a tube from the stump of the gall-bladder, after having first placed one or two sutures in the gall bladder bed If, on the other hand, there is any question about the patency of the duct, the remains of the mucous membrane should be dissected away, or should be destroyed by the cautery In either case a tube must be brought from the stump to the surface

2 **Removal of the mucous membrane.**—When the gall bladder is embedded in the substance of the liver, or is buried in a dense mass of adhesions, it may be impossible to carry out a formal excision In these circumstances an attempt may be made to remove the mucous membrane entire After the contents of the viscus have been dealt with, a longitudinal incision is made along the under-surface of the gall bladder down to the submucous coat The lining membrane is then separated by blunt dissection and gentle traction A ligature must be applied to its neck and a tube brought from this point up through the remaining coats of the gall-bladder to the surface There will be some little hæmorrhage from the inner surface of the outer coats, which must be dealt with either by obliterating sutures or by gauze packing

3 **Destruction of the mucous membrane by the actual cautery** (Rutherford Morison)—This method may be employed when the others are not available The gall-bladder is first emptied and is then split along its inferior surface from fundus to neck and, after being thoroughly dried, the secreting part of the mucous membrane is destroyed with the thermo-cautery The walls are then drawn together with catgut sutures in such a way as to obliterate the cavity, or, if they are too thickened and rigid, the cavity is packed with gauze

4 **Electro-surgical obliteration.**—In this method the gall bladder is laid open from fundus to neck and the mucous membrane thoroughly and completely destroyed by electro-coagulation The halves of the viscus are then sewn together and the abdomen closed without drainage The idea is to avoid the risk of hæmorrhage and spread of infection by destroying the inner layers of the gall bladder without opening up the cellular tissue between the viscus and the liver The serous layer is preserved and used as a covering for the treated area

The depth and extent of the coagulation can be regulated by the strength of the current the type of the electrode and the pressure with which it is applied When the wall of the gall bladder is very thick or an abscess has extended into the liver deep coagulation will be necessary Aseptic necrosis results and healing is satisfactory This method has recently been strongly advocated by several surgeons * Pribram has had personal experience of more than a thousand cases of all types with very good results It is claimed that as drainage is dispensed with there is very little post operative discomfort and recovery is rapid and complete It is stated that the method is particularly suitable for cases with suppuration and especially when there is extension of the inflammatory process to the liver



A B

Fig 424 A —Acute infection of gall bladder with ulceration into liver
B —Electro surgical obliteration of gall bladder
(Reproduced by permission from the Lancet 1932 Oct 28)

Technique —The gall bladder is exposed by any convenient incision Proper exploration of the extent of the disease and of the condition of the deeper ducts is the first step The operation area must then be walled off with wet saline packs If the gall bladder is voluminous it is aspirated after which the cystic duct is exposed divided and ligatured in the usual manner When easy of access the cystic artery should also be ligatured The gall bladder is then laid open along its whole length and the contents evacuated After being thoroughly dried the whole of the mucous membrane is destroyed by electric coagulation (Fig 424) and the walls are then sutured together thus leaving a smooth serous surface When there is inflammatory extension into the liver or there are fistulæ into the stomach or bowel the viscera are not separated but any track into the liver or the

* Lancet Oct 29 1932 ii, 977

orifice of a fistula is thoroughly coagulated and the remainder of the viscus dealt with as described

Another plan (Thorek) is to cut away the redundant part of the gall-bladder, leaving only that area which is attached to the liver to be treated by electro-coagulation This is then covered over by a detached piece of the triangular ligament or a free omental graft sutured in position In both methods the abdomen is closed without drainage

Enthusiasts urge that this method should be adopted in place of cholecystectomy and not simply kept in reserve as an alternative plan It probably has a considerable field of usefulness in dealing with acute and badly infected cases, but there is no doubt that its advocates have exaggerated the alleged disadvantages of the occasional cholecystotomy or the more usual cholecystectomy, which in expert hands are thoroughly satisfactory operations

Special points in the removal of the gall-bladder for cancer.—The preliminary examination is most important, for the surgeon must take special care to see that there are no secondary deposits in the liver Direct extension to the latter does not always contra-indicate operation, but in the presence of scattered secondary deposits, removal of the gall bladder is useless It is also important to examine the ducts, as extension in this direction may make removal impossible Some surgeons advise that in all cases a wedge resection of the liver should be carried out (*see* p 772) Direct involvement of the colon does not necessarily contra-indicate radical operation, but it does mean that partial colectomy will be required in addition to the cholecystectomy If the gall-bladder cannot be removed it should on no account be opened, unless there is some such complication as empyema This proceeding does not relieve symptoms, a mucous or bile fistula invariably persists, and the growth is apt to fungate through the sinus

Results of operations for cancer of the gall-bladder —The primary mortality is probably about 10 per cent In cases that are recognized as frankly malignant by the naked eye at the time of the interference, the ultimate prognosis is very bad for the great majority die from recurrence within twelve months On the other hand, when the condition is discovered fortuitously as the result of microscopic exmination of the excised gall-bladder, the results are much more favourable, and this is one of the strong arguments in favour of cholecystectomy

Choledochotomy

The common duct may be opened in any of its three parts, and the operation employed in each case has needlessly attained the dignity of a special name Attention must be drawn to the anatomy of the duct, as shown in Fig 396, p 750 The illustrations showing the relations of calculi to the various parts of the duct emphasize some of the

technical difficulties (Figs 425 426) Lymphatic vessels and some glands lie along the course of the common duct and the latter when enlarged and especially if calcareous may closely simulate calculi in the duct The dilatation of the ducts varies within wide limits and the lumen may be like that of the small intestine or just large enough to admit the Desjardin forceps The thickness of the wall is also very variable for it may be so thin that the bile can be seen through it or so thickened that it is quite difficult to cut into the lumen It must be

Fig 425

Fig 426

Diagrams made from actual specimens of calculi in common duct

Fig 425 —Calculus impacted in the pancreatic portion of the duct in a position suitable for removal by transduodenal choledochotomy

Fig 426 —Showing how a calculus impacted in the same situation has ulcerated into the duodenum through the side of the duct the papilla remaining intact (*Guy's Hospital Museum*)

clearly realized that the supraduodenal portion of the duct is frequently much obscured by pathological changes The infundibulum of the gall bladder is often adherent to the duodenum and the latter is frequently drawn up over the duct by other adhesions When these are separated the duct comes into view and by pressing the duodenum and pancreas downwards an exposure of the supraduodenal part of the duct beyond its anatomical limits can easily be obtained This exposure is further enhanced by the use of the loin support and in occasional circumstances it may be made still more accessible by mobilization of the duodenum (Kocher) This is carried out by gently tearing through or incising the peritoneum just to the outer side of the

duodenum as it lies over the right kidney It is enough to make quite a small opening in this membrane, as the remainder of the mobilization can all be done by blunt dissection with the fingers which easily manipulate the duodenum forwards and inwards The incision of the supraduodenal or free portion of the duct is undoubtedly the operation of choice, and in the great majority of cases the calculi can be removed from this part

Special preparation.—This is very important, but has been sufficiently dealt with at p 785

Technique.—In many of the cases jaundice will be a complication, and will demand the gentlest manipulations and the most scrupulous regard for hæmorrhage, even the smallest vessels being caught and tied This precaution applies to the parietal wound as well as to the deeper parts The abdominal incision must be adequate, and all the additional aids to exposure will have to be employed In very fat subjects none of these aids will make the operation an easy one, and a headlight may be very useful The steps are as follows —

1 General exploration and palpation of ducts
2 Exposure of the common duct
3 Incision of the duct
4 Extraction of calculi and exploration of ducts from within
5 Treatment of the gall-bladder
6 Arrangements for drainage
7 Toilet and wound closure

As a first step the gall bladder is examined, and if it contains stones, the decision as to their treatment will be made, but it is better to deal with them after the common duct part of the operation is over, as the viscus forms a convenient handle and a safe means of making traction on the duct, thus helping to bring it nearer the surface and to straighten it The gall-bladder is also the best guide to the duct Among the numerous adhesions to the omentum and to neighbouring viscera, the surgeon must be on the look out for internal fistula, which may be hidden in an adhesion of the infundibuliform type (Fig 118, p 799) These must be separated before the common duct can be exposed In jaundiced cases the gall-bladder is usually small and shrivelled but it may be voluminous and may further obscure the parts, when it must be emptied as a preliminary Occasionally the gall-bladder is so much shrivelled from previous inflammation that it is practically non-existent In these circumstances it is of very little value as a guide to the duct, and certainly cannot be used as a tractor Again the duct may be so obscured from adhesions that its exposure is long and tedious and produces much traumatism In either of these circumstances it may be possible to rotate the duct, as pointed out by Moynihan * The manœuvre is carried out by the fingers of the left hand which are passed along the gastro hepatic omentum just above the pylorus and

* "Abdominal Operations," vol ii 3rd edn.

stomach As the fingers are flexed, the hand and wrist are bent over to the patient s left In this way the posterior surface is exposed and may be incised *When the* common duct is exposed as it lies in the edge of the small omentum it can be palpated between the first two fingers of the right hand in the foramen of Winslow and the thumb in front This can often be most conveniently done if the surgeon stands on the opposite (left) side of the patient (Fig 427) To palpate the

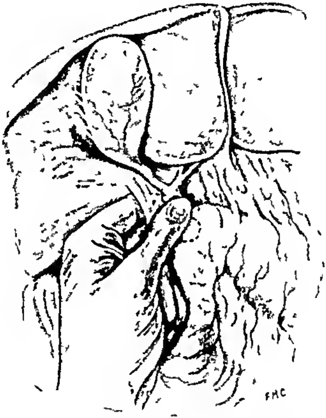


Fig 427 —Method of palpating common duct

whole duct the head of the pancreas and duodenum must also be felt in the same way *If the presence of stones is confirmed*, it must be determined whether they are movable in the duct or fixed If they are free care must be taken that they do not slip up into the hepatic ducts out of reach If they are fixed in the duct behind the duodenum the surgeon must endeavour to manipulate them either into the supraduodenal portion of the duct or into the bowel This is done by steady pressure on the lowest part of the stone, and in this manipulation considerable force may be used, provided great care is taken not to pull or push on the duct in such a way as to cause tearing A process of ' coaxing is often the most successful This examination will

probably determine where the duct is to be opened, and in the great majority of cases the supraduodenal portion will first have to be incised

(1) The supraduodenal operation —Packs are arranged (*a*) in front of the small omentum to keep back the stomach, (*b*) below to control the duodenum and colon, and (*c*) in the hepatic pouch to catch any of the contents of the duct that may escape in that direction The liver is held aside by an assistant who also makes gentle traction on the gall-bladder Adhesions having been separated as described, and the duodenum pushed well down, the duct is now exposed by gently tearing through the overlying peritoneum with dissecting forceps Where exposure is difficult it will be an aid at this stage gently to lift the duct forwards by the fingers of the left hand in the foramen of Winslow Sometimes the parts about the duct are so thickened or infiltrated that they will not strip, but very often in these circumstances the forceps happen to tear into the duct and disclose its lumen Sometimes it is not possible to identify the duct except by incision, in this case the greatest care must be taken not to carry the knife by the side of the duct straight into the portal vein or even through the duct into the vein When there is great difficulty in identifying the duct, it may help to use a small exploring syringe When all else fails, the gall bladder and cystic duct may have to be slit up until the lumen of the common duct is reached

The duct having been exposed, the next step is to secure it on either side of the proposed incision, either in catch forceps or with a catgut stitch the ends of which are left long to be used as guys While it is steadied by traction on the forceps or sutures, a longitudinal incision is made into its lumen The incision must be large enough to give exit to the stone or admit the forceps necessary for its extraction It will seldom be less than half an inch in the first instance, and if necessary may be conveniently enlarged upwards by fine-pointed scissors Care must be taken not to injure vessels which may cross the duct Any that are seen should be caught and divided between forceps The escape of bile at once identifies the lumen, but sometimes the content is only clear mucus, and this is often so in cases of long standing obstruction If the secretion has been dammed up, there may be a considerable quantity which must be soaked up by gauze or removed by suction If the stone is just at the site of the incision, it may escape or be easily extruded by manipulation, or it may be caught in forceps and extracted An elusive stone is sometimes very difficult to locate, and when such a stone is felt it is best to fix it between the finger and thumb and to cut directly on to it, sutures or catch forceps being placed in the wall of the duct after the incision is made Or it may be easier to catch the portion of duct containing the stone in a pair of long ring-forceps, thus leaving the fingers free for other manipulations Whenever possible, the lumen of the duct is explored by the finger, which is the most reliable probe At the present day, operations for obstructive jaundice are carried out at a much earlier stage than formerly and the ducts have usually not had time to get sufficiently

dilated to admit the finger In these circumstances suitable forceps must be passed both downwards (Fig 428) and upwards and if any difficulty is experienced in dislodging calculi and always when there is débris the gall stone scoop should be used Very small stones fragments of larger calculi or bile sand are removed by passing a small strand of gauze or a tape into the duct and slowly withdrawing it There is sometimes a lateral pouching of the lower end of the common duct in which stones or débris may be hidden and the scoop is most likely to remove them or the débris may be extracted entangled in the strand or ribbon of gauze In any case it is best to pass a sound $\frac{3}{16}$ in in diameter (a Lister's bougie answers the purpose very well) along the duct into the duodenum for the surgeon may then feel assured that any fragments which have evaded his search will safely pass into the bowel If it has not been possible to extract the stone by combined use of the forceps and manipulation it should not be broken but some other route for its removal should be chosen

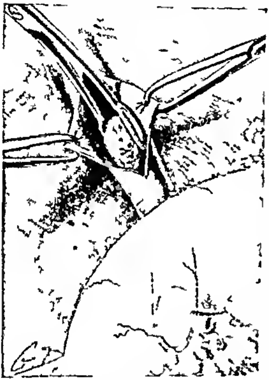


Fig 428 Removal of stone from lower end of common duct with the Desjardins forceps
(Modified from K. ...)

The stone having been extracted drainage must be arranged as the consensus of experience is against complete closure of the duct by suture If there is (a) jaundice of long standing (b) much detritus in the duct (c) clinical or other evidence of bile sepsis or (d) any question about the duct being cleared of stones then it should be drained by a tube passed into its lumen towards the hepatic duct The proper type of tube to use is shown in Fig 407 1 p 793 Its end should be cut obliquely so as to expose as much of its lumen as possible and in addition there should be a lateral hole A No 10 or 12 Jacques catheter with the end cut off serves the purpose very well The incision in the duct should be closed by interrupted sutures up to the point where the tube emerges The T shaped tube so often recommended is not advised for if it is left for more than a few days it cannot be removed without tearing the incision in the duct and there is a risk that the end piece may break off and be left in the duct In most cases drainage of the interio

of the duct is not necessary but the incision in its wall should be drawn together by a few interrupted sutures great care being taken not to narrow the lumen Exact closure is not necessary As some bile leakage is almost certain a small soft tube (¼ in diam) should be threaded down to the duct on the end of one of the sutures in the way indicated for cholecystectomy or after suture of the duct (Fig 431 p 837) While the succeeding steps of the operation are being carried out the tube is temporarily held *in situ* either by a catgut suture tied over but not through it or else by a forceps caught on the edge of the duct

The gall bladder is now dealt with according to the indications remembering that in jaundiced cases it should not be removed This conservative attitude is dictated by the necessity of reducing the risk of hæmorrhage and because it is among the common duct cases that recurrences or relapses are the more frequent Subsequent operations on the common duct are greatly facilitated if the gall bladder remains as a guide Should there be a consequent pancreatitis the viscus may be invaluable for cholecystenterostomy Since drainage from the duct or its neighbourhood has been provided it is not usually necessary to drain the gall bladder independently though this may be done as the simplest way of finishing the operation If there has been much bleeding and oozing persists a gauze strand had better be packed over the area where the duct has been bared and in any event a soft rubber tube or tissue drain should be brought from the hepatic pouch Any exposed gauze is protected from contact with the viscera by rubber tissue and the drains are brought from the abdominal wound together The gauze and hepatic pouch drain are cut short and the common-duct tube is fixed to the skin by a silkworm stitch and carried through the dressings into a baby s feeding bottle (*See* Fig 408 p 794)

(2) **The retroduodenal route**—This is only to be employed when a calculus is so firmly impacted in the second part of the duct that it cannot be manipulated downwards into the duodenum or upwards into an accessible position in the first part of the duct or removed by suitable forceps through a supraduodenal incision In actual practice this method is very rarely necessary and it becomes less so as with increasing experience the means of thorough exposure of the supra duodenal part are better understood The success of the operation depends on the thorough mobilization of the duodenum This is carried out by incising the peritoneum on its outer side and then gently separating it inwards In this way the duodenum and head of the pancreas can be rotated until their posterior surface is exposed If the duct has been opened above a sound may be passed downwards to act as a guide There is however little difficulty in identifying the duct since the impacted stone is a sufficient guide The duct over the stone may be caught in catch forceps and then incised longitudinally During this step the pancreas may have to be incised After the extraction of the stone the duct is explored as already described If

there is also an opening in the supraduodenal part drainage is better carried out from it otherwise the tube may be introduced into the retroduodenal opening or brought from its margin If not to be used for drainage the opening is closed by three or four interrupted sutures of fine chromic catgut which do not enter the lumen of the duct In any event a soft rubber drain is brought from the vicinity Provided drainage from the neighbourhood of the incised duct is arranged there need be no anxiety about suturing the duct for the edges tend to lie together when the parts are allowed to fall into position None the less the edges of a large opening in the duct should be drawn together by a single suture The duodenum and head of the pancreas readily resume their former position and do not require fixation

(3) The transduodenal operation —This is only to be used when a calculus at the lowest part of the duct cannot be removed with forceps from above or manipulated into the duodenum by pressure with the fingers or pushed into the bowel with a sound In actual practice it is very rarely required which is fortunate for it is not a very satisfactory operation

The duodenum is isolated and brought into the wound and if this cannot be done easily it should be mobilized for the purpo e The bowel is packed round with gauze and an incision about 1½ in long is made in its long axis opposite the middle of its second part At the conclusion of the operation this incision is carefully sutured in the *opposite* direction to obviate narrowing The incision in the duodenum is held open by catch forceps or stay sutures and the orifice of the duct on the inner wall is either seen or is first identified by touch The papilla may be disappointingly difficult to locate When found it may conveniently be drawn up into the wound and thus made more accessible A catch forceps or catgut stitch is used for this purpose but must take a deep hold of the bowel wall otherwise it readily cuts out If the stone is actually arrested at the orifice it may be removed by simply incising the latter but if it is impacted a little higher up the inner wall of the bowel and the duct must be divided directly over it (Fig 425) Steps must be taken to prevent the stone slipping back into the dilated duct above and in any event after its removal the duct must be cleared by forceps and scoop or gauze If the opening made in the duct is large it may be closed if the normal orifice is sufficiently patent If there is any doubt about the patency of the orifice or if the duct contains much débris the incision should merely be diminished by one or two sutures passed through both the wall of the duodenum and the duct The actual orifice must be left larger than normal so that drainage may be free and there may be no contraction during healing If there is hæmorrhage it may be controlled by stitching the wall of the duct to the wall of the duodenum at one or two points

After treatment —Any gauze and the drain from the hepatic pouch should be removed on the fourth day The common-duct tube must remain for at least a week and after its removal bile will dis

charge for perhaps another week The complications and sequelæ are those associated with any jaundiced case, and the best prophylactic is free bile drainage, though excessive loss of bile may be deleterious (*see* pp 801–2)

Special difficulties of choledochotomy.—In fat and bulky patients this operation may be extremely difficult and hazardous The most important point is to secure good exposure The guide to the duct is the foramen of Winslow, and even when this is obliterated by adhesions, its situation marks the posterior limit of the small omentum in which the duct lies The downward separation of the duodenum is the next most helpful step The surgeon must never incise what he takes to be the duct, until he has satisfied himself that the structure is in the position in which the duct normally lies Identification may be greatly aided by cautious use of the hypodermic syringe A fine needle may be inserted obliquely backwards and upwards in the position of the duct while at the same time the plunger is withdrawn It must be remembered that in long standing cases the content of the duct is often clear, the so called "white bile" Care must be taken not to thrust the needle right through the duct into the portal vein Even when the duct is properly identified and exposed, there may be difficulty in determining whether a nodule felt is really a stone This difficulty is especially great when the suspected nodule is in the second or third part of the duct The only safe rule is to incise right up to any lump the nature of which cannot be otherwise determined Chronic inflammatory thickening of the wall of the duct, a localized pancreatitis or a new growth of the duct or the ampulla are the conditions most likely to lead to errors

Removal of Calculi from the Hepatic Ducts

It is not necessary to give this operation any special name Calculi may be firmly impacted in the hepatic ducts but more commonly they are free, and either slip up from the common duct or are found when the latter is explored When impacted they may be coaxed down into the common duct or an incision may have to be made directly over them When free they may be washed out by the first rush of bile, or they may be caught with the Desjardins forceps When they are known to have slipped out of reach or can be felt but not withdrawn, they may be coaxed down by using the forefinger like a piston (Mayo) If there is any doubt about the hepatic duct being cleared it is essential to pass as large a tube as possible well into its lumen for drainage and thus to encourage the subsequent escape of the calculus

Other Methods Useful in Duct Surgery

Cholangiography and ether instillation.—Cholangiography is a diagnostic method in which some radio opaque substance is injected into the biliary tract This is done through a tube, like a catheter, size 8 or 10, which is passed into the common duct towards its lower end

where obstruction is likely to persist The duct must be closed firmly round about the tube by suture

As a rule lipiodol is employed it should be warmed and injected slowly into the common duct while observations are made with the flourescent screen at regular intervals Mirizzi (1931) and others have used this method during the course of operation and designated the plan operative cholangiography As a rule it is employed as a secondary diagnostic procedure a week or ten days after a tube has been inserted into the duct as part of the operation of choledochotomy By this means information may be obtained of the presence site and sometimes the nature of a persisting obstruction It requires patience care and expert X ray technique

Pribram (1932) has shown that the instillation of ether may dissolve an obstructing calculus The plan is advocated rather than retroduo denal or transduodenal choledochotomy as both these operations carry a mortality of about 20 per cent The drain tube fixed in the duct must first be emptied of bile with a syringe which is then emptied washed out with ether and recharged and used to inject gently into the duct As a rule only about ½ to 1 c c is injected at a sitting and only drop by drop If too much is used the patient complains of a sense of internal fulness or pressure When the patient is comfortable 1 or 2 c c of liquid paraffin are introduced into the tube which is then clamped and left so for as long as the patient is at ease The procedure may be repeated every day At the end of a week a further cholangio gram is made and treatment carried on or otherwise as indicated

Though some calculi dissolve readily the instillations may have to be carried on for as long as eight weeks to clear the duct The cessation of biliary drainage or the appearance of bile in the stools suggest that the obstruction has disappeared but it is well to confirm the patency of the duct by repeating the cholangiography By these methods Pribram (1939) claims that the mortality following the treatment of common duct stones has been reduced to 5 per cent in his hands

Secondary operations on the biliary system—In these circum stances great care should be exercised in proper preparation The main difficulty will be from the presence of adhesions but though they may cause difficulties and embarrassment *there are no cases in which* they cannot be overcome by patient careful work When one of the vertical incisions has previously been employed it is often a great help to re open the abdomen by the Kocher incision. In this way the parietal adhesions are avoided and the gall bladder and ducts may be approached from above and it is often easier to find a plane of cleavage The edge of the liver and the gall bladder (if still present) or the notch for the gall bladder are the first landmarks at which to aim

The colon and the duodenum are often densely adherent to the gall bladder site and the operator must be on the look-out for tears which may look trivial in the making but are usually uncomfortably large when they come to be repaired Suture is best carried out as soon

as the part is sufficiently exposed When the gall-bladder has been removed there is no sure guide to the common duct except a knowledge of its anatomical position It may assist identification to put the fingers in the foramen of Winslow and gently lift forward the edge of the gastro-hepatic omentum But very often the foramen is obliterated by adhesions, and in that event the duct can only be found by a fine exploring syringe

When the necessary anatomical features are exposed but not before, the operation indicated can be carried out I have found that *secondary cholecystectomy is comparatively easy and satisfactory* Secondary operations on the ducts may be extremely difficult Special care must be taken to control hæmorrhage and to guard against hepatic insufficiency during convalescence It is perhaps in secondary operations on the ducts that cholangiography and the instillation of ether may find their greatest usefulness

Results of operative interference with the gall-bladder and ducts — In the majority of cases the operations will have been required for gall stones or their complications but the subject is inseparably connected with that of cholecystitis, and in a review of the results the surgical treatment of that condition must be included The subject may be considered under three heads

1 Immediate mortality
2 The relief afforded
3 Recurrences

1 *The immediate mortality* depends for the most part on the condition demanding the operation When calculi are limited to the gall-bladder and unattended by complications, the mortality may be as low as 1 per cent , whereas in operations involving the common duct in the presence of jaundice, and with septic complications, it may be as high as 25 per cent But even in cases most favourable from the pathological standpoint and where there is no question of complications, the general condition of the patient and the anatomical features have some bearing on the results Many of those who require operations for gall stones are elderly, they are often stout, the heart is apt to be fatty, and there is a tendency to bronchitis It is a striking fact that the mortality among males is about twice as great as among females (Edington, Walters) All these features have an influence on the immediate results Fortunately, with the onward march of surgery, operations for gall stones are being carried out at a much earlier stage of the disease, and patients now frequently come to the surgeon when younger and in better condition Nevertheless, the results finally depend on judgment in deciding on the stage of the illness at which to interfere, on the selection of the proper procedure after the abdomen has been opened, and on the technical ability in carrying this out Some surgeons have special opportunities of acquiring experience in this class of work, and have operated upon large numbers of cases with surprising results During 1938, at the Mayo Clinic 980

patients were subjected to cholecystectomy with a mortality of 1 8 per cent There were also 308 operations for benign lesions of the bile ducts with 6 5 per cent of deaths nearly half the patients in this group were jaundiced But quite apart from the work of specialists in gall bladder surgery the results are very good Taking a continuous series of cases operated upon by a general surgeon and reckoning all the various conditions and operations together the mortality works out at not quite 6 per cent In those cases in which the stones were limited to the gall bladder but including the complications which may occur in this situation the percentage was 3 and for the common-duct cases nearly 14 In the hands of ordinary competent surgeons at the present time the mortality of operations for gall stones with their complications when limited to the gall bladder should not be more than about 3 per cent and when they have invaded the common duct about 5 per cent or if jaundice is present 10 per cent This section does not attempt to deal with the comparative mortality of the individual operations which have been employed

2 3 Relief afforded and Recurrences —In some cases persistent symptoms are due to pre-existing disease of the stomach or duodenum or to chronic appendicitis or cirrhosis of the liver Very rarely stomach symptoms developing after operation are due to adhesion of the pyloric region to the gall bladder area which is an argument for its proper protection after cholecystectomy There are also cases in which recurrence of symptoms follows rapidly on an operation of expediency carried out because the condition of the patient was not such as to justify those measures which the pathological condition indicated Such events cannot be looked upon as recurrences though they appear so to the patient Even when the operation performed has been properly indicated and carried out about 10 per cent of the patients complain of recurrence These patients can be divided into two groups—(1) those who have never experienced complete relief and (2) those who have been well for a varying period and have then had a return of symptoms

In the *first group* the commonest causes are calculi left behind pancreatitis unrecognized malignant disease and stricture of the ducts Fully developed malignant disease of the gall bladder is never likely to be overlooked but a chronically inflamed thick walled glistening gall bladder which is the type that often harbours early cancer may readily be left unless cholecystectomy is frequently practised Overlooked calculi usually lurk in the common duct and especially in cases in which there has been long standing obstruction and in which lateral pouching of the duct has developed In some of the cases calculi found at a second operation have probably been lying in the hepatic ducts from which they have been flushed into their new position When in the gall bladder they will be found about the neck or in the cystic duct Some degree of pancreatitis is present in about 20 per cent of the common-duct cases and persistence of the infection in the duct presumably lights it up again Stricture of the ducts is a

condition which may be anticipated if there has been difficulty in carrying out excision of the gall-bladder There will usually have been suggestive symptoms during the immediate convalescence, so that it is not likely to develop as a surprise

In the *second group*, in a series of cases analysed by Judd of the Mayo Clinic, the interval of complete relief averaged two and a half years, but recurrence may follow ten or twelve or more years after the primary operation In this group there is usually recurrence of stones It may be due to the persistence of the original infection or stones may form around some fragment or fragments left behind or around a foreign body such as a suture (Fig 414 p 800) The persistence of the primary infection is illustrated by cases in which at the original operation, the gall bladder showed evidence of gross infection but without stones, while at the second operation stones were found Recurrence of calculi is usually limited to cases in which the gall-bladder has only been drained at the original operation and is one of the strong arguments in favour of removal of the gall bladder rather than simple drainage * In fact, recurrent symptoms of all sorts are much more frequent after the drainage operation, and are due to a persistence of the biliary infection, or to a fresh cholecystitis, or to a recurrence of calculi or to cancer After cholecystectomy symptoms may recur, but are then most likely to be due to pancreatitis, to recurrence of calculi in the ducts, or to adhesions to the site from which the gall bladder has been removed In a certain proportion of cases, further operation fails to explain the recurrence of symptoms, which are then probably due to some little-understood type of hepatitis Repeated recurrence of calculi also takes place, and these rare cases have an interesting bearing on the question of the gall stone diathesis It has been suggested that this diathesis is the result of toxins which are elaborated in the spleen and excreted by the liver Acting on this assumption, splenectomy has been deliberately practised to deal with such recurrences Overlooked acholuric jaundice may be the explanation of some disappointing recurrences The whole question of the after results has been carefully studied by James H Saint *

OPERATIONS FOR OBSTRUCTIVE CONDITIONS NOT DUE TO CALCULI

The conditions that come under this head may be —

1 Chronic pancreatitis
2 Malignant disease of the head of the pancreas
3 Malignant disease of the bile-ducts
4 Involvement of bile-duct in a new growth of the duodenum
5 Obliteration or stricture of the ducts following injury

The association of jaundice with a distended gall bladder is usually due to malignant disease of the head of the pancreas or to chronic pancreatitis In the absence of signs of dissemination the diagnosis cannot be made with absolute certainty until the abdomen is opened.

* *Brit Journ Surg* 1933 xxi, No 90 p. 299

and even then the surgeon may still be in doubt. Since surgeons became aggressive in their attitude to the gall bladder many cases of obliteration or stricture of the hepatic or common duct have occurred as the result of surgical injury during cholecystectomy.

When the abdomen is opened it is first necessary to make a careful examination to discover the exact nature of the obstruction and to determine whether or not it can be dealt with directly. For instance a new growth of the ampulla or the pancreas may be removed * or an obliteration of the bile duct treated by reconstruction of the duct. When the obstruction is of such a nature that it cannot be removed it may be treated by anastomosing the gall bladder to some part of the gastro-intestinal canal or one of the ducts or very rarely a raw ed surface of the liver. Sometimes it may be expedient to establish external drainage and to perform a short-circuiting operation as a secondary proceeding or to unite a resulting biliary fistula to stomach or small bowel.

Cholecystenterostomy

Preparation.—All that has been said about the preparation of the jaundiced patient is especially important in these cases.

Technique.—The second part of the duodenum is the ideal site for the anastomosis but it is not always possible to get the gall bladder to lie in contact without tension. In these circumstances the anastomosis may be made either to the stomach or to the hepatic flexure of the colon. Anastomosis between the gall bladder and the stomach is undoubtedly safe and satisfactory; it is also technically easy and physiologically sound. In any case the anastomosis should be made by direct incision and continuous suture.

It may first be necessary to draw off some of the contents of the gall bladder as otherwise it may be too tense to handle and the needle will puncture its lumen. In any event very fine needles and suture material should be employed. If the bile is thick and tarry it may not flow through the trocar and the fundus will have to be incised for its evacuation. Incidentally it may be noted that the chances of relief from the interference are slight when the contents of the viscus are thin, clear and watery or mucoid. A light bowel clamp is applied to the fundus of the gall bladder and to a portion of the viscus selected for the anastomosis. The openings to be united should be at least an inch long. It is probably better to excise a piece of the gall bladder wall about an inch in diameter; when this plan is adopted there seems to be less tendency to contraction of the anastomosis. The actual union is made with continuous catgut, the first layer passing through all the coats so as to be watertight and hæmostatic, the second layer uniting the peritoneum only. One or two additional Lembert sutures should be applied here and there and any tags of omentum or neighbouring appendices epiploicæ tacked to the line of union. When the duodenum is selected for the anastomosis the incision in its wall should be transverse. If the stomach is to be

* See Gordon Taylor, *Brit Med Journ* 1942, i, 119, where the whole question is reviewed.

used the anastomosis may be made wherever the gall-bladder lies most snugly against it, and this will usually be near the pylorus. When the union is to the hepatic flexure the incision should be made through one of the longitudinal bands. The abdomen should be closed without drainage.

When the gall-bladder is not present, or is shrivelled or inaccessible, the operation just described is not possible. The surgeon may then unite any part of the dilated ducts to the nearest and most accessible part of the bowel (*choledocho-enterostomy*) or stomach, great care being taken to avoid tension, and the anastomosis being protected by neighbouring fat. If the ducts are not available for the anastomosis, then the operation of *hepato-cholangio-enterostomy* may be carried out.

Choledocho-enterostomy

The preparation of the patient and the preliminary steps of the operation are the same as for any common duct procedure. The common duct may be divided transversely and its open end implanted into an incision in the duodenum, but as a rule it is much better to make a lateral implantation as indicated in Fig. 429. When the common duct is much dilated, the operation is carried out exactly like cholecystenterostomy and there are no special difficulties. As a rule, clamps cannot be applied either to the duct or the duodenum, but they are not essential. If the duct is very distended or tense it may be aspirated as a first step. Great care must be taken with hæmostasis. The surgeon must also take care not to narrow the anastomosis by too great finesse in burying the deep sutures. When the duct is only moderately dilated, the incision will have to be made oblique or nearly vertical to secure a sufficient opening. It should be wide enough to admit the tip of the forefinger.

Fig. 429.—Choledocho-enterostomy. First stage.

If these operations are going to be very difficult and involve much separation of the tissues, with consequent risk of hæmorrhage in jaundiced patients, they had better be carried out in two stages—first drainage, followed some weeks later by secondary anastomosis. For this latter purpose the abdomen is opened through the original incision and the gall-bladder is detached from the parietes. If the opening in the fundus is not large enough for the anastomosis it must be extended. The anastomosis is then made as already described. The results of this two-stage operation, both immediate and remote, have been very satisfactory. It has the advantage that in cases of doubt it provides an opportunity for carrying out cholangiography for diagnosis.

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Complications—In some cases though jaundice is relieved distressing symptoms may follow These take the form of rigors fever vomiting and often recurrence of jaundice and are due to ascending cholangitis If this condition does not yield to treatment it may be worth while re opening the abdomen for the anastomosis may be contracted and can be re made If stenosis at the site of union is not the explanation Mallet Guy has suggested that the area should be excluded by dividing the stomach near the pylorus closing both ends and making a gastro-enterostomy

Results—These depend on the condition demanding the interference Short circuiting in cancer of the pancreas or ducts is a most disappointing operation and carries a mortality of about 40 per cent It often fails to relieve itching and jaundice and would not be worth while were it not that in a certain proportion of the cases the supposed cancer turns out to be the result of pancreatitis When that is so the results are often very good and this is what may be expected in any non malignant condition This operation has the unusual merit of revocability

OPERATIONS FOR BILIARY FISTULA FOR INJURIES TO THE DUCTS AND FOR OBLITERATIONS

Reconstructive Surgery of the Biliary Ducts

Biliary fistulæ—In this section only *external* biliary fistulæ are dealt with Such fistulæ may give exit to bile or only to mucus In the former case all the bile secreted may escape in this way or part may find its way into the intestine by the normal channels The flow may be intermittent or continuous and sometimes the fistula may heal for a time only to break out again The mucous fistula may behave in a similar way In either case gross infection may be superadded For successful treatment it is essential to have some idea of the cause of any particular fistula

Spontaneous fistulæ —These are due to suppuration in the gall bladder with discharge of an abscess on to the surface They are usually mucous fistulæ due to impaction of a calculus in the neck of the gall bladder The external opening may be in almost any situation on the right side of the body though usually it is about the umbilicus These cases may be looked upon as examples of the neglect of surgery and are rapidly becoming extremely rare

Postoperative biliary fistulæ —The great majority of the fistulæ met with at the present day are complications or sequelæ of operations for the relief of gall-stones though they may of course occur after drainage of the biliary tract carried out for obstruction of uncertain origin and they may occasionally follow accidental injuries Overlooked calculi are the commonest single cause of persistent fistulæ following surgical intervention but many cases follow surgical injuries of the ducts The comparative frequency of these latter cases during

the last few years and the flood of literature dealing with them are a striking commentary on the dangers that may attend cholecystectomy

Indications for surgical interference—In many cases it is difficult to decide when a fistula may be said to be permanent or to have reached a stage at which surgical interference is justified because when the biliary tract has been deliberately drained there is a wide variation in the quantity of the fluid discharged and in the time it continues although ultimately to be followed by recovery Generally speaking external bile drainage seldom continues for longer than three weeks after removal of the tube and if it does so the probable further duration depends on the amount of bile reaching the intestine If there is enough to colour the fæces the patency and the continuity of the duct are demonstrated and continued external drainage need not occasion alarm for bile may be discharged to the surface for months and yet healing and restoration to the normal channel may follow If on the other hand bile is never found in the evacuations or there is evidence of only slight intermittent discharge into the bowel the fact suggests some condition which will require surgical intervention In some cases the fistula closes intermittently and if when it is closed the patient is perfectly well and the evacuations are normal in colour spontaneous cure may confidently be anticipated On the other hand if when the fistula closes the patient feels seedy and little or no bile reaches the stools and there is a tinge of jaundice with perhaps slight pyrexia some mechanical obstruction certainly exists The question however is further complicated by the knowledge that this amount of obstruction may be due to an overlooked fragment of stone which may safely pass in the course of time and this is suggested by repeated attacks of colic In these circumstances it may be well to wait When deepening jaundice follows the closure of a fistula there can be no doubt that there is some mechanical obstruction which will require surgical intervention The combination of persistent biliary fistula with jaundice can occur though it is not easy to explain how it is produced It is a good working rule to consider the necessity for interference if a fistula continues after three months A pre operative diagnosis of the cause of the fistula is very helpful but it is often extremely difficult to make The matter is complicated by the fact that the primary operation has often been carried out elsewhere and important information may not be obtainable For these reasons every case must be considered as a problem which requires a review of the illness preceding the fistula of the conditions found at the operation if ascertainable and of the symptoms which have attended the fistula as well as a careful investigation of the condition at the time of the contemplated interference The method of cholangio graphy (*see* p 825) with lipiodol may furnish great help If a remaining calculus is the cause this may be dissolved by the instillation of ether (Pribram *see* p 826)

The operation which may be required—When a fistula is due to fixation of the opened gall bladder to the parietes and there is no

obstruction in the ducts, it is sufficient to separate the viscus and to close it by suture, the abdominal wall also being repaired Or the gall bladder may be removed When overlooked calculi are the cause they must be dealt with according to the principles already laid down Obliteration or stricture of the cystic duct always demands cholecystectomy Strictures of the common duct may occasionally be successfully treated by plastic operations or by divulsion Recent injuries to the great ducts may be dealt with by direct end to-end suture Old injuries and obliterations demand union of the gall-bladder to some part of the gastro-intestinal canal, but when that viscus has been removed, plastic restoration of the duct or implantation of its proximal end into the duodenum are the methods available Some few cases have been successfully treated by implanting the fistulous tract directly into the stomach or some part of the bowel

Special preparation.—These patients are often in poor condition, are anæmic, and usually suffer in a marked degree from the special proclivity to hæmorrhage which attends jaundice Some days should therefore be spent in preparation on the general lines already indicated on p 785 Blood transfusion may be of great value, and may give just that stimulus which will ensure a good result The discharging sinus should be carefully dressed with moist perchloride gauze so that the surrounding skin may become charged with the antiseptic

General observations on the surgery of ducts—These structures all contain a good deal of elastic tissue, and in consequence when partially divided they tend to gape, but if the division is complete the ends separate widely and immediately contract, thus favouring subsequent occlusion They are only very loosely connected to the tissues in which they lie, and these form a sort of a sheath in which they easily move Their mucous membrane is fortunately possessed of great reparative power, and tends to grow longitudinally, and is capable of bridging a considerable gap or making up for a considerable deficiency if there is the merest shred to guide it in the proper direction Ducts do not atrophy appreciably from disuse, though they readily contract and become obliterated as the result of infection, with its attendant inflammation and consequent development of scar tissue *In the repair of torn or divided ducts the most important point* is to secure approximation of the ends, it is not necessary to obtain accurate apposition, but there must be no tension The sutured part should be wider, i e have a bigger lumen, than the normal duct This is secured by enlarging the ducts to be sutured by making a small longitudinal slit in the ends (Fig 431, p 837)

Technique.—These procedures may be among the most difficult and anxious in surgery, and should only be attempted by those who are accustomed to operate on the liver and its ducts Every accessory may be required and the operations should only be undertaken in a properly equipped operating theatre where good daylight or bright artificial light is available, where ample assistance can be obtained.

and where everything that can possibly be required is at hand A mechanical table is almost essential so that the height can be easily adjusted to suit the type of subject and in order that the reverse Trendelenburg position can be adopted and varied at will A skilled anæsthetist and an experienced assistant with whom the operator is accustomed to work, are indispensable The incision will be deter

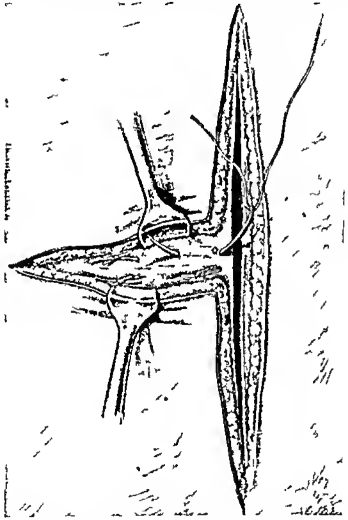


Fig 430 —Method of preventing retraction of rectus by fixing it to its sheath with a few sutures preparatory to transverse division

(Modified from Sir Henry Gray's figure in Brit Journ Surg)

mined partly by the operator's preference and partly by the circumstances of the case For instance, if a previous operation has left the gall bladder adherent to the posterior part of an oblique incision it will almost be necessary to adopt the same type of incision though it may be varied as to its exact situation and length When the choice is entirely in the operator's hands a vertical incision through the inner third of the rectus, or nearer the middle line, carried right

up to the costo xiphoid angle and extending down as far as the umbilicus or even lower will best serve the purpose If still more room is required it may be obtained by cutting the rectus across either at the middle of the vertical incision (Fig 480) or just above the umbilicus In most cases a very thorough separation of adhesions is essential in order to reach the ducts and it greatly helps the exposure of the parts to separate not only the gall bladder but also the dome of the liver from the parietes Whenever possible adhesions should be divided between forceps and the ends ligatured even the smallest bleeding point must not be neglected The surgeon should endeavour to determine the pathological condition present and decide on the plan to be adopted as soon after the preliminary incision as possible For instance if the gall bladder has already been removed and it is clear that anastomosis must be made between the proximal end of the divided common duct and the duodenum as few adhesions should be separated as possible since in these circumstances they form a useful bond between the duodenum and the liver and serve to prevent the exposure of the low resisting cellular tissue

It may be necessary to restore the common bile-duct (*a*) immediately after its division as when it is injured as the result of a crush or during the course of an operation such as cholecystectomy or (*b*) at some remoter period when the ends have become widely separated and cicatrized and are buried in massive adhesions Fine 6/0 chromic catgut is the most suitable material for the sutures It is usually best to employ interrupted stitches because they can be more accurately placed and there is less risk of narrowing the union

(*a*) RESTORATION OF COMMON DUCT BY APPROXIMATION OF THE ENDS

In *recent cases* the first step is to identify the ends They will have been cared for in deliberate excisions but in other cases will probably be widely separated The separation is much exaggerated when the parts are exposed as for a common duct operation The use of the Robson position (loin support) traction on the gall bladder and the displacement of the duodenum downwards all tend to increase the distance between the ends The upper end will usually be identified by the flow of bile but if this is not obvious some bile may be milked down by the fingers The lower end may have retracted behind the duodenum but may usually be found by displacing the duodenum downwards When the ends are found the next step is to see if they can be approximated without tension This can often be accomplished in a surprising way even over a gap of an inch and a half If there is difficulty removal of the loin support and mobilization of the duodenum will accomplish a great deal Sutures are then introduced They should be of chromicized catgut (size 6/0) and should be passed with a fine round needle in a holder They can often be made to secure a good hold without actually perforating the lumen of the duct Comparatively few sutures are required and the knots must be outside the duct wall When possible two sutures should

be introduced into the tissues behind the duct and should be tied These not only help to approximate the parts but also obliterate the dead space there Three stay sutures should then be introduced into the duct itself the posterior part is first dealt with and care must be taken that corresponding walls of the duct are approximated i e to see that the ends are not rotated Before putting in the anterior sutures the surgeon must satisfy himself that the lower part of the duct and the duodenal orifice are patent If drainage is indicated it must be provided This is best done by splitting up the antero external wall of the upper end of the duct for ½ in and *bringing* a catheter out through this slit from the proximal end of the duct Many surgeons recommend a T shaped tube which lies in the suture line but this is wrong in principle for ducts heal more kindly and

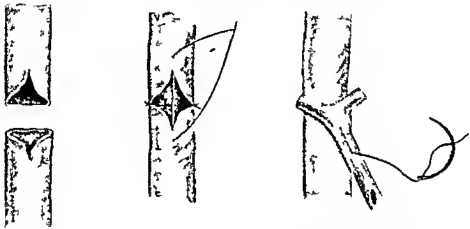


Fig 431 —Repair of common duct The ends have been enlarged A split rubber tube is run down to the sutured area on one of the sutures

with less risk of stricture when there is no foreign body in contact with the suture line and when the secretion is conducted to the surface from the proximal side There is also a risk that the T tube may tear away the union when it is removed or that it may break a portion being left behind in the duct The region of the anastomosis is covered by the neighbouring tissues or by some tags of the gastro hepatic omentum When it is not considered necessary to drain the duct directly a soft rubber tube must be brought from the region of the sutured duct to the surface as in this method of direct suture there is almost invariably a little leakage (Fig 431) Any tube left in the duct should be removed in ten days or a fortnight after which the escape of bile will probably soon cease Sometimes only a narrow bridge of one part of the duct remains This should be most carefully preserved the duct being repaired over a rubber tube as mentioned in the next section

In *old cases* it may be extremely difficult to find and identify the ends Where there is a bile fistula the track will lead to the upper cut

end of the duct When the duct is obliterated the part above the obstruction will be distended but it is not readily seen as it may be very near the liver and in fact the experience of the Mayo Clinic has shown that it is usually almost flush with that viscus and buried in the midst of a mass of scar tissue Of course if still present the gall bladder is the guide to the duct but if as is usual it has been excised the gall bladder notch guides the operator to a mass of scar tissue in which the upper end of the duct is embedded It may often be identified by introducing a hypodermic needle and withdrawing

Fig 432 —Repair of common bile-duct by direct suture
(Modified from W J Mayo's figure)
The T tube is sometimes recommended for drainage but is best omitted

some fluid but it must be remembered that the bile in these circumstances is nearly or quite colourless Great care is necessary to avoid the portal vein which may bulge into the space formerly occupied by the duct When the upper end is identified it must be opened up to its fullest extent As a rule this can easily be done by introducing the points of a pair of forceps along the track of the exploring needle and then separating the blades widely as they are withdrawn (Fig 433) The lower end is not so difficult to find it will not be distended but on the other hand it will not be atrophied In great difficulty and uncertainty the duodenum may be opened and a probe passed

up from the ampulla If the upper end will not easily reach the lower so that the two may be sutured together without tension it is not worth while proceeding with an attempt to perform direct anasto mosis and the condition must either be dealt with by restoration as described on the next page or by hepatico duodenostomy

Fig 433 —Diagrammatic representation of the steps necessary to identify and deal with the stump of the divided common duct

(b) RESTORATION WHEN THE ENDS CANNOT BE APPROXIMATED

This may have to be carried out immediately as for instance when a large section of the duct has been removed in the excision of a growth or a stricture or as a secondary operation when the ends have become widely retracted In these circumstances the gap may be bridged by one of the following plans

1 **Over a rubber tube** (Sullivan) —The tube to be employed is about the size of a No 10 Jacques catheter It is introduced into the upper end of the common or the hepatic duct for about an inch which will presumably be close to the union of the right and left hepatic ducts and is fixed to the duct by a catgut suture or an en circling ligature The tube then bridges the interval between the ends of the duct and is passed through the lower end until it can be felt projecting for about an inch into the duodenum (Fig 434) Whenever possible some part of the duct is brought together over the tube in the hope of establishing continuity of the mucous membrane at some one point The tissues round about are then drawn over the tube and it is finally completely wrapped round by omentum which is fixed to either end of the duct to the duodenum and to the tissues in the vicinity by a few points of suture If the lower end of the duct is not available or the tube cannot be introduced it should be passed directly into an oblique opening made into the duodenum and the wall of the latter fixed to it by purse string suture

and then tucked in over it as in the Witzel method of gastrostomy. Mouat* found it more satisfactory to fix the tube into the duodenum as the first step. It is wise to provide for external drainage. The rubber tube usually finds its way into the bowel but it has been *vomited*. *Eventually the continuity of the duct* is restored. The time taken for the tube to be voided has varied from about three weeks to six months. The new duct will not be lined by mucous membrane and stricture is likely to follow and has done so in several recorded cases.

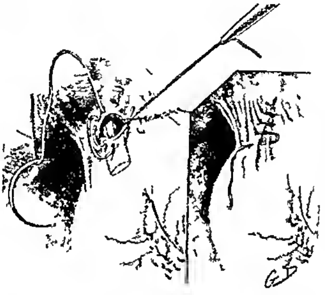


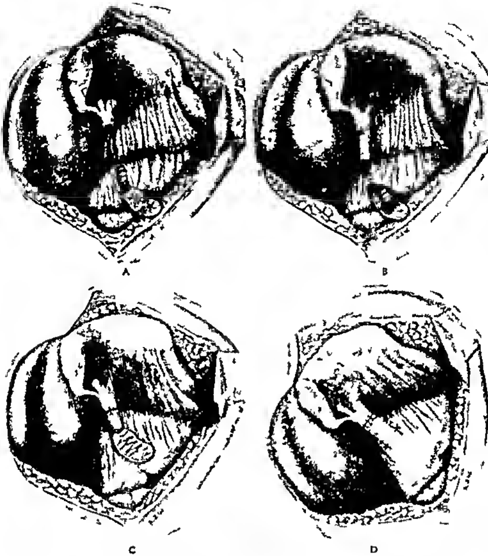
Fig. 434.—Reconstruction of common bile duct over rubber tube. It is better to use interrupted sutures and much thinner catgut for the duct.

(Modified from W. J. Mayo's figure.)

2. By a flap cut from the duodenal wall (Walton)†.—It is claimed for this plan that a mucous membrane lined duct is provided which is therefore not likely to contract. The upper end of the common duct having been isolated, the superior border of the duodenum is drawn upon and is fixed to the structures about the hilum so as to diminish the gap as far as possible. The largest sized rubber tube which it will admit is then passed into the upper end of the duct and is fixed to it by suture. A flap is then cut from the upper surface of the duodenum and is sutured to the margin of the duct and around the tube, the lower end of which is introduced into the bowel. The union may wisely be supported by an omental graft. The method is well shown in Fig. 435. As a precautionary measure a soft tube is brought from the neighbourhood to the surface.

* *Lancet*, July 23, 1938, i, 181.

† A. J. Walton, *Brit. Journ. Surg.*, Oct. 19 1, ix, 169.



F g 435 —Reconstruction of common bile duct by Walton s method

(Re-d aun f om Brit Journ Su g " October 1971 by pe mission of S r A J Walton)

A Duct divided and opening made into duod num with flap cut from latte an l turned down B Rubber tube sutured into duct and open ng in duod nu par ally closed C Tube inserted i to du denum and latter d awn up as close as poss b e to co mon duct D Di od n l flap sutured around tube thus cor pleti g the reconstruc ion

3 By direct union of the hepatic duct to the duodenum (hepatico-duodenostomy)—This method is the only one available when the gap to be bridged is very extensive It has certain advan tages which lead the Mayos to look upon it as the method of choice and with this view I certainly agree The first case operated upon by W J Mayo was reported in 1905 and the patient was known to be alive and well fifteen years afterwards

Technique —The duodenum must be located but fortunately the distal end of the common duct need not be identified The proximal

end of the hepatic duct must be found and all that has been said in the previous section applies to this stage of the difficult operation The stump of the duct is as a rule flush with the liver and the best guide is the gall bladder notch which leads down to a mass of tissue in which the duct will almost certainly be found When identified it is freed as much as possible, but even so only a very short piece will be available *The duodenum is drawn* up to the mass of scar tissue round about the site of the duct, but it should not be separated

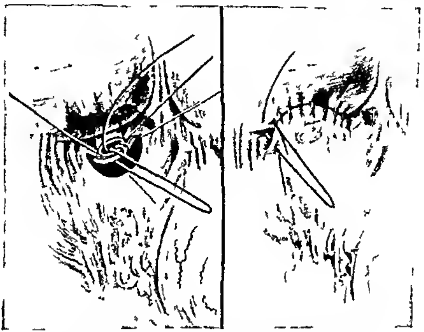


Fig 436 —Technique of hepatico-duodenostomy

A, Exposed end of the hepatic duct being sutured to a large opening in the duodenum. A posterior layer has been introduced, and a similar through and through continuous stitch is being applied

B The free anterior margin of the duodenal opening is being sutured to the surface of the liver to bury the duct completely but leaving a large interval between the duodenal mucosa and the duct to allow for contraction Additional sutures may be required to reinforce the union, some tags of adhesions being drawn down and fixed to the duodenal wall

The suture material should be catgut and the deeper stitches are best interrupted.

(*Re-drawn from figures in Ann Surg March 1921 by permission of Donald C Balfour Mayo Clinic*)

posteriorly, as it is only necessary to have access to a small part of its anterior wall A few sutures should be inserted behind the site of the proposed anastomosis to draw the bowel as near to the stump of the duct as possible and to diminish the risk of pull on the anastomosis A slightly curved flap is then dissected out of the entire thickness of the duodenal wall over an area which will leave an opening into the bowel about 2 5 cm in diameter It should be realized that there is always a tendency to contraction and that the opening *should be large enough to admit the forefinger* (Fig 436, A) The edge of the flap is sutured with catgut to the posterior

and lateral walls of the hepatic duct, so that there is a muco-mucous union of the posterior and postero lateral two thirds of the duct The free edge of the anterior margin of the opening in the duodenum is now sutured to the anterior edge of the stump of the duct and to the capsule of the liver or to the scar tissue just in front of the remainder of the hepatic duct, thus completely burying it, or, in other words, covering the opening in the duodenum with part of Glisson s capsule and neighbouring scar tissue Next, a much wider area of the duodenum is drawn up and sutured to the liver to cover the anastomosis and to take off all tension Neighbouring omental tissues are then packed round the anastomosis and fixed with a point or two of suture Though leakage *is not invariable*, a *soft* rubber drain should always be brought from the neighbourhood, and if there is no discharge it may be left until the first dressing at the end of a week, or otherwise until discharge nearly ceases Balfour of the Mayo Clinic reports* that the results, both immediate and remote, are very satisfactory, and I myself, with considerable subsequent experience, can fully endorse this statement So far as Balfour knows, bile has always been properly delivered into the duodenum, and few cases of subsequent stricture have occurred

Divulsion of the strictured area of the common duct with forceps. For those cases in which the stricture is in the pancreatic portion of the duct, the result of ulceration, it has been found satisfactory to open the supraduodenal portion of the common duct and pass a pair of dilating forceps through the strictured area until it is completely divulsed Strictures in this vicinity are usually in the nature of a diaphragm, and will often tear like paper when forceps are passed through them into the duodenum After divulsion a piece of rubber tube may be placed through the strictured part of the duct, and left projecting for half an inch into the duodenum It should be fixed by a single stitch to the wall of the duct and will in due course be safely discharged into the bowel In any event the neighbourhood of the incision in the duct should be drained for a time

In the more difficult cases it will occasionally be found necessary to open the duodenum and expose the papilla before undertaking divulsion of the stricture

Transplantation of external biliary fistula into the duodenum.— This operation, which was first carried out as long ago as 1905, must be looked upon as an intervention of necessity and not of choice It may be expedient when the multiplicity and density of adhesions renders exposure of the stump of the hepatic duct impossible or when an attempt at direct anastomosis has failed, with a resultant fistula When confronted with what looks like inevitable failure the surgeon may be wise to endeavour *deliberately to* make an *external* bile fistula which can later be implanted into the bowel

Technique —The first step is to pass a catheter into the fistula as

* *Ann Surg.*, March, 19–4 lxxix 343

far as it will travel The instrument must not fit too tightly or it may cause necrosis of the wall of the track The abdomen is then opened by an incision including the fistula about its centre The fistulous track is then dissected free of the parietal tissues and down towards the liver It should be cored out with a considerable amount of surrounding tissue to ensure its nutrition The nearest accessible portion of the duodenum is then found so that the mobilized tract can be laid against it without tension An opening which will just admit the track is made into the viscus and the fistula is drawn into it by an attached suture in the same way as the ureter is drawn into the bowel in transplantation The incision in the duodenum must then be closed around the transplant Further protection is given by surrounding the union with a piece of omentum tacked here and there by a catgut stitch

Choice of operation —When an injury to the common duct is recognized at the time it occurs it will usually be possible to effect repair by direct suture and this should be the surgeon s aim If for any reason the ends of the duct cannot be approximated and the gall bladder remains it should be united to the duodenum or stomach the proximal end of the duct being ligatured When the gall bladder has been removed the choice will generally lie between reconstruction of the duct or direct anastomosis of the hepatic duct to the duodenum Occasionally a limited stricture of an accessible part of the common duct will lend itself to plastic repair—longitudinal division with suture in the opposite direction Similarly a localized area of stenosis might be excised and continuity restored by direct end to-end suture Stenosis at the lowest part of the common duct can often be successfully treated by divulsion In these matters the experience of the staff of the Mayo Clinic is unrivalled and they regard hepatico-duodenostomy as the operation of choice in the majority of cases

Results —The surgical procedures which have just been described are very serious undertakings and the mortality following them is necessarily high and not always truly represented by the published figures Repeated operations have sometimes been necessary and small fistulæ have remained in spite of the most adroit surgical proceedings In general terms it is fair to say that about one third of the cases die of the immediate effect of the accident another third from the operative intervention necessary for repair and that among the survivors there are many late deaths Even when the operation has been successful in the sense that a fistula has been closed or an obliterated duct restored complete cure has often been marred by some degree of persistent narrowing or recurrent sepsis in the ducts In some cases calculi have formed after these operations and have been successfully removed Nevertheless several cases have been recorded which have remained well over periods of from five to twenty years and this is the only criterion of success

CHOLEDOCHECTOMY

This operation may be required in order to deal with a primary malignant growth of the extrahepatic bile ducts, or an extension of malignant disease from the gall bladder or from the stomach or colon, or for resection of a stricture or obliteration following simple ulceration or some type of injury It may also be part of an operation for the removal of a tumour of the ampulla of Vater Primary malignant growths are usually small and well localized, and may easily be over looked or mistaken for gall-stones A certain type of growth may remain local for a considerable time, and does not show a tendency to secondary deposits This especially applies to tumours of the ampulla

Preparation.—The general preparation recommended for jaundiced patients must be carried out with special care, and steps must be taken to combat the anæmia, for which purpose a preliminary blood-transfusion may be exceedingly valuable

Two-stage operations.—The operation of choledochectomy may be tedious and difficult, and may involve much separation of adhesions, as well as the division of many small vessels which are difficult to catch and tie Prolonged operation and minor traumatism conduce to bleed ing and make the worst possible combination in jaundiced patients The surgeon must therefore consider the advisability of operating in two stages The first stage would consist of an exploration to determine the exact condition present and the feasibility of a subsequent radical operation This preliminary interference must be conducted with the utmost gentleness and the greatest regard to hæmorrhage, and with all the precautions that are proper to operations in jaundiced patients Having determined that radical operation holds out good prospect, the surgeon provides external bile drainage via the gall bladder, whenever possible, though it may have to be directly from a dilated duct If the conditions are such that prolongation of life and addition to comfort are problematical as in some of the cancer cases it will be wise to be content with a palliative anastomosis to the gastro intestinal tract, and thus to conclude the operation in one stage With non malignant conditions a later interference after preliminary drainage may make all the difference, as the risk is greatly lessened when jaundice and its attendant cholæmia have disappeared

Technique.—The incision must be one of those already described for the deeper ducts, as adequate exposure is essential The steps are as follows —

1. Thorough exploration with special regard to secondary deposits in cases of growth
2. Isolation of the duct above and below the spot where it is to be divided
3. Division of the duct and decision as to the method of repair.
4. Repair or substitution
5. Toilet of the operation area

Great care must be taken at this stage not only to exclude the presence of secondary deposits but to see that there is no such infiltration of surrounding parts, e g the portal vein, as might prove an obstacle to successful removal at a later stage of the operation With recent advances in the technique of vascular surgery, there need be no hesitation in removing a portion of the portal vein as this vessel may safely be diminished by suture, and it seems probable that even resection of a part of the vein with end to-end suture need not prove an insuperable bar The actual division of the duct must be strictly transverse, and steps must, of course be taken to prevent the ends retracting until a decision has been made as to their disposal If the ducts are dilated to twice or thrice their normal size and they can be approximated without tension, end to-end union as described in the previous section, may safely be employed At this stage great help may be secured by mobilization of the duodenum When the divided ducts are not much larger than normal, or there is difficulty in approximation, the surgeon must decide whether to implant the hepatic duct into the duodenum or carry out one of the reconstruction methods already described In this decision he must be guided by his own experience and the conditions present in the particular case There is not yet enough accumulated experience to enable anyone to say definitely which method ought to be employed as between reconstruction of the bile-duct or hepatico duodenostomy, though the Mayo Clinic are enthusiastic about the success of the latter

Operation for Cancer of the Ampulla of Vater

This condition is best dealt with by the transduodenal route A probable diagnosis having been made as the result of the examination the duodenum is opened by a longitudinal incision over the site of the mass felt in its lumen The latter can then as a rule easily be drawn forward for examination If the diagnosis is confirmed and previous examination has shown that there are no secondary deposits in the liver and no enlarged glands, the excision may be completed The base of the tumour with half an inch of healthy mucous membrane round about, is encircled by an incision which goes completely through the bowel wall opening up the cellular tissue between the duodenum and the pancreas By making gentle traction and using the dissecting forceps the tumour with the duct is isolated and this separation must be continued until the common duct is seen free half an inch above the tumour The pancreatic duct must also be identified (Fig 437) Both ducts are now caught in forceps (not crushed) so that they cannot retract, and are cleanly divided The cut ends are then sewn together with a stitch, and their open mouths are conjointly fixed by a few points of suture to the wall of the duodenum in such a way that mucous membrane is continuous with mucous membrane It is often impossible to identify the pancreatic duct, in which case it may safely be left to look after itself, care being taken not to obliterate by suture the

area in which it may be expected to lie. If the opening in the inner wall of the duodenum is too large, either the upper or the lower part is diminished by suture. If there is a free escape of bile into the lumen of the bowel, nothing further is necessary, but if there is any doubt the gall-bladder should be independently drained, or a tube may be passed up the common duct and left projecting for half an inch or so into the duodenum, where it is fixed by a stitch to its wall. The duodenal incision is now sutured in the transverse axis so as to increase rather than diminish its lumen.

If jaundice is present the operation may be done in two stages. Whipple and his co-workers* have devised a very radical method which, they hope, will bring more cases within the range of operability and secure better late results. The first stage comprises posterior gastro-enterostomy, ligation and division of the common bile-duct and

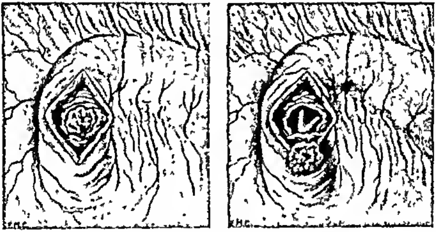


Fig. 437.—Diagrammatic representation of removal of new growth of ampulla of Vater by trans-duodenal route.

cholecystogastrostomy. At the second intervention, three or four weeks later, the descending part of the duodenum is resected, with the growth and a V-shaped portion of the pancreas. The ends of the duodenum are closed, and the pancreas is repaired by suture, the duct being ligatured and allowed to retract†. This drastic method will require extended trial to show whether it gives better long-term results. (Fig 440, p 857.)

Results.—In new growths the operative mortality has been between 35 and 50 per cent, but it may be expected to improve with more efficient preparation of jaundiced cases. Recurrence is almost to be expected, as even in the most favourable cases it may not be possible to excise enough healthy tissue with the growth. Some few cases on record were alive and well up to fifteen years after operation (Upcott).

* *Annals of Surg.*, Oct. 1935 cii, 763.
† *Gordon Taylor, Brit Med Journ* 1942, ii 119

Congenital Cysts of the Common Bile Duct

Simple drainage on marsupialization has usually been followed by exhaustion severe infection hæmorrhage and death Excision is seldom feasible and when attempted has invariably proved fatal The best results have followed anastomosis of the cyst to the stomach or duodenum In very ill patients simple drainage may be useful but only in the expectation of carrying the patient on to such time as anastomosis to some part of the alimentary canal can be more safely undertaken

Technique —One of the vertical incisions will probably give the best exposure If the cyst is very large and tense it should be rendered flaccid by aspiration The part of the cyst which lies most comfortably in contact with the stomach or duodenum should be selected for the anastomosis The union should be made as described under cholecystenterostomy (p 830) Great care must be taken to secure accurate hæmostasis If the contents of the cystic dilation are grossly infected temporary external drainage should also be provided A small drain (size No 12 rubber catheter) should be inserted and securely fixed by a purse string or other type of suture Tags of neighbouring loose tissue or a portion of omentum should be fixed around the tube to guard against leakage To ensure that the opening will close spontaneously after the removal of the tube the cyst must not be attached to the parietes Such a drain can probably be safely removed about the tenth day

Congenital Atresia of the Bile Ducts

When this condition is suspected exploration should be carried out when the child is about four months old If the gall bladder is present cholecystenterostomy is indicated In the absence of this viscus the blind end of the common duct must be implanted into the duodenum with or without the temporary support of a tube

Results.—Ladd of Boston* stated that 37 per cent of the cases presented possibilities of successful surgical intervention and of those operated upon 60 per cent recovered Patients were alive and in good health from six months to ten years after operation

* *Annals of Surg*, Oct., 1935, cii 742.

CHAPTER XVII

OPERATIONS FOR DISEASE OF THE PANCREAS

By G. GREY TURNER

Anatomical and physiological observations.—A thorough knowledge of the *surgical anatomy* of the pancreas is of the greatest importance, as its close relations with many important organs in the upper abdomen lead to complications in diagnosis and prognosis and add very much to the difficulties attending surgical operations The pancreas lies transversely across the abdomen at the level of the first and second lumbar vertebræ, and as it is entirely behind the peritoneum, it is covered by the stomach and the lesser sac, the posterior layer of which lies in front of it It rests on the aorta, having the cœliac axis immediately above it and the superior mesenteric artery and vein below and behind Its *tail* touches the spleen, a point to remember in doing splenectomy, the *body* is in such close relation to the stomach that it is often invaded in the saddle ulcer of that organ, and the *head* is in close contact with the pylorus and the first and second parts of the duodenum, which forms three-fourths of a circle above, to the right, and below But perhaps the most important relation is to the bile passages The common bile duct, in its course to its termination in the duodenum, passes behind the head of the pancreas, and in two cases out of three is actually surrounded in this part of its course by pancreatic tissue

The pancreas has two ducts—one, the duct of Wirsung, which in all but a small percentage of cases (10 per cent) joins the common bile-duct just before its duodenal opening at the ampulla of Vater and the smaller, the duct of Santorini, which does not always function It follows, then, that, while on the one hand diseases of the head of the pancreas may interfere with the permeability of the common bile-duct, on the other hand gall stones or infections of the common bile-duct may have a direct influence on the main duct of the pancreas In practice it is found that cancer of the head of the pancreas and even chronic inflammatory hyperplasia, are often the cause of jaundice The commonest cause of pancreatitis is infection associated with gall-stones in the bile-passages Whether this is brought about by direct infection along the ducts or secondarily through the lymphatics, is undecided, and is not a matter of great importance from the operative standpoint The anatomical fact that the common bile-duct and the duct of Wirsung unite to open into the duodenum by a common orifice is generally accepted as the governing factor in the causation of acute hæmorrhagic pancreatitis

Physiology —The pancreas is a racemose gland comparable with the salivary glands, with the modification that between the secreting acini lie the islets of Langerhans which elaborate insulin

The external secretion is strongly alkaline, has a specific gravity of from 1012 to 1014, and a composition of 98 5 per cent water and 1 5 per cent solids The secretion is under both nervous and hormonal control The parasympathetic vagus fibres when stimulated cause a flow of viscid juice rich in ferments while secretin, elaborated when hydrochloric acid from the stomach comes in contact with duodenal mucosa, causes a copious secretion of juice of low specific gravity and poor in ferments

It is probable that the pancreatic ferments (trypsinogen amylase lipase, maltase and very small amounts of rennin) are elaborated in a relatively inert form and are only activated by enterokinase a product of the duodenal mucosa This is certainly true for trypsinogen When the juice is activated by contact with the intestinal secretion or with bile it becomes highly destructive to the tissues other than the intestinal mucous membrane It is this property that accounts for fat necrosis, hæmorrhages and destruction of cellular tissue in pancreatic disease or injury The same effect may be produced on the pancreatic tissue when there is retrojection of bile along its main duct, and this is probably the commonest cause of pancreatitis

Insulin is produced by the islets of Langerhans and its main function is to regulate the metabolism of the carbohydrates When this function is at fault diabetes mellitus results The islets are scattered throughout the gland but are most abundant in the tail It is said that a normal gland contains more than one thousand times more insulin-producing tissue than is necessary for the normal needs of the body Total pancreatectomy in the experimental animal is followed by the development of diabetes and wasting which is not entirely prevented by the administration of insulin Raw pancreas given by the mouth is of value though not entirely protective A diet rich in lipoids particularly lecithin helps to maintain health in a depancreatized animal Large portions of the human pancreas have been surgically removed without serious metabolic disturbance Diabetes only rarely results from such destruction of the gland as may follow inflammations Even temporary glycosuria is infrequent in pancreatitis

Indications.—Operations on the pancreas are performed for tumours (simple and malignant), cysts and pseudocysts, stone in the pancreatic duct, acute and subacute infections and injuries The latter are dealt with at p 659 Chronic infections and jaundice due to cancer of the pancreas are treated indirectly by operations on the bile passages

General operative considerations.—The following special points must be borne in mind when it is necessary to operate on the pancreas Patients whose condition demands such interference are often exceedingly ill, particularly cases of acute inflammation The pancreas can be exposed either through the gastro hepatic omentum, the gastro colic omentum or the mesocolon (Fig 442, p 862) and the route chosen will depend on any bulging which may be present into one or other of these situations If there is nothing to give a lead, then it is probably best to use the route through the gastro-colic omentum

In the more chronic cases there are often strong adhesions to the surrounding parts and especially the posterior surface of the stomach and sometimes inflammatory exudates find their way into this viscus The operator must take care not to anticipate nature in this respect for a hole torn into the back of the stomach in these circumstances may be very difficult to close The vascularity of the pancreas is much increased in the presence of inflammation and quite apart from large trunks the smaller vessels are capable of giving rise to serious bleeding The substance of the gland is always friable especially in the presence of disease It should be torn as little as possible for pancreatic secretion very readily escapes and this may have most serious consequences For this reason a drain should always be brought from the neighbourhood although it need not actually be in contact with the pancreas Any raw area on the latter should be covered whenever possible either by drawing the neighbouring tissue over it and fixing it with sutures or by using omentum for the purpose

TUMOURS

There have been few recorded cases of removal of tumours from the pancreas Such tumours if innocent are cystadenomata or fibromata Adenomata of the islets of Langerhans have of recent years been recognized as one of the causes of hypoglycæmia and several examples of their successful removal are on record Primary malignant tumours may be sarcomata or carcinomata

Non malignant Tumours

In actual practice opportunities for dealing with tumours of the pancreas are rare Encapsulated growths may be successfully enucleated and those near the tail can be removed together with that part of the organ In all cases raw areas must be drawn together or covered by omentum and drainage must always be provided

The Surgical Treatment of Hypoglycæmia

Technique of removal of adenomata —In the management of these cases there must be the closest co operation between physician and surgeon Where so many important chemical examinations are involved it is for the physician to select the appropriate time for the operation and to supervise the necessary pre-operative and post operative régime Complete relaxation of the abdominal wall is essential and for that reason spinal anæsthesia is recommended It is suggested* that a wide transverse incision about 2 in above the umbilicus and dividing both recti should be employed (Fig 488) It certainly gives a very good exposure but an ample mid line incision with good retraction is also adequate The gland is approached through the gastro colic omentum which is divided sufficiently to give an unimpeded view The tumours are most commonly found towards the tail end which should be examined first They may present as purplish

* Whipple and Frantz *Annals of Surg* June 1935 ci, 1299

nodules slightly raised above the surface of the gland and 1 to 2 cm in diameter. If the suspected tumour is not obvious, the pancreas should be carefully palpated by running the fingers along its surface when the adenoma may be detected like a buried pea. But the tumour may be situated on the posterior or deep surface which should be examined before concluding that no adenoma is present; to expose the back of the gland the peritoneum must be incised along its lower border. These tumours may also be multiple and, when one has been found, a careful search should be made for others.

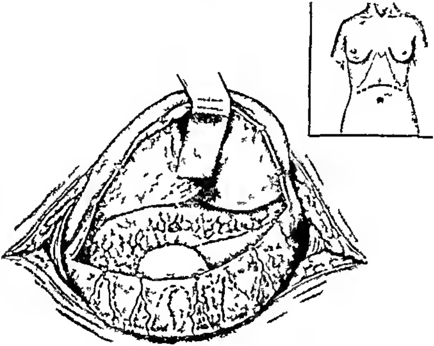


Fig 438.—Exposure of pancreas through gastro colic omentum for exploration and removal of adenomata. The parietal incision is shown inset
(Whipple and Frantz redrawn)

The line of cleavage between the adenoma and the gland can be demonstrated with a blunt dissector, with which instrument the tumour is usually easily enucleated. Vessels that bleed must be caught and carefully tied with the finest catgut or silk. If there is oozing from the bed from which the tumour has been enucleated, or if the pancreatic substance has been torn, the sides of the bed should be drawn together with one or two fine stitches. It is probably safer to bring a small rubber drain ($\frac{3}{16}$ in in diameter) from near the tumour site up through the parietal incision. Should there be no leakage no harm will ensue and the tube can be removed at the end of a week.

In some cases there is quite a copious discharge of pancreatic juice and the tube is a necessary safeguard, for when it has been omitted pancreatic fluid has sometimes accumulated in the lesser sac, causing alarming symptoms of peritoneal irritation and necessitating secondary drainage. The gap in the gastro-colic omentum should be drawn together with a few stitches and the parietes carefully repaired by layer suture The rectus sheath should be drawn together with interrupted sutures, but it is not necessary to put stitches in the muscle itself

If an adenoma cannot be found, it is recommended that ⅘ of the pancreas, that is to say, the tail and the body excluding the head, should be removed

Partial pancreatectomy.—Technique—The stomach must be held well up and the colon down, and it will still further help if the loin

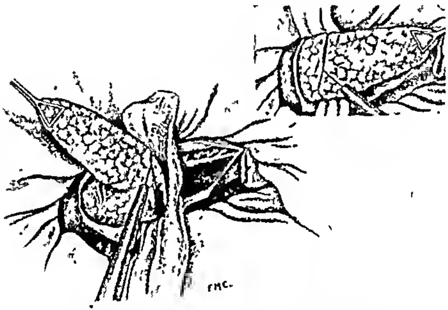


Fig. 439—Partial pancreatectomy. (*After Mallet Guy, redrawn*)

is elevated, as in gall-bladder operations The peritoneum is incised along the lower border of the gland. The tail is first separated from its connections and is gently drawn downwards The branches from the splenic artery passing into the upper border of the gland will be exposed, and must be carefully caught, ligatured and divided If the splenic artery and its veins lie very closely along the upper border of the pancreas it will be wiser to put a temporary ligature around them at an early stage or deliberately to ligature and divide them. It will often facilitate the operation to remove the spleen, but this is not necessary simply because the artery has been tied, for its other vascular connections are sufficient to prevent necrosis. Once the pancreas has been released from its vessels it can be readily separated from the tissues

in which it lies and can be drawn towards the surface. It is not necessary to clamp the gland at the site of the proposed division; in fact it is better not to. The division should be made deliberately so that any vessels, or even the duct, may be seen and caught before being severed, otherwise these structures retract and are often difficult to catch. It is better, though not essential, to divide the gland in a V shape so that the flaps may be sutured together to cover the raw surface (Fig. 489). It is sometimes recommended that the gland should be cut across with the diathermy knife or seared with the cautery, but that is not essential. After removal the edges of the posterior peritoneum should be drawn together to cover the gland bed. The stump of the gland should not be completely buried, and in all cases a rubber drain should be brought from its vicinity through the parietal incision. While cases have healed without leakage, in others there has been a free escape of pancreatic secretion, sometimes continuing for weeks. Among the published cases the mortality has been very low, probably due to the fact that the operation has only been undertaken by experienced surgeons. But such an operation must always be potentially serious and should never be lightly undertaken. The obesity which is a frequent accompaniment of hypoglycaemia has often proved a serious embarrassment to the surgeon. The results in both types of intervention have been most encouraging. An extensive literature has already accumulated about this subject.*

MALIGNANT TUMOURS

In suspected malignant disease of the pancreas, when there are no unequivocal signs of dissemination, an abdominal operation may be justifiable—

(*a*) to establish the diagnosis;
(*b*) to consider removal of the growth even if that means partial or total pancreatectomy;
(*c*) to relieve jaundice and itching by anastomosis of the gall bladder to one of the hollow viscera;
(*d*) to palliate the growth by insertion of radium seeds.

Malignant tumours are usually carcinomata, and as they so frequently arise in the head of the gland and give rise to obstructive jaundice they have acquired an evil reputation. The condition usually takes the form of a diffuse infiltration and it is only very rarely that a more defined and localized growth is found. In the diffuse type it may be very difficult to decide on the nature of the enlargement. On rare occasions tumours of the islets of Langerhans removed for hypoglycaemia have on histological examination proved to be malignant. Apart from this accidental finding there are some few cases on record where well-defined malignant tumours nearly as large as a fist have been encountered. When such tumours arise in the tail or even in the body they may lend themselves to extirpation together with that part of

* The papers by Whipple and F[illegible] [illegible] by Russell F[illegible] [illegible] Journ. Med., New Series, Jan. 193[illegible], vol. [illegible], are most helpful.

the pancreas in which they are situated Their removal must follow the lines of partial removal of the gland which has just been briefly described As in all operations for abdominal cancer, the surgeon must first be satisfied that there is no dissemination to the liver, that glandular invasion is not extensive, and that local extension of the growth, especially posteriorly, does not render the attempt at removal unwarrantable

Technique.—It is essential that exposure should be adequate, and the surgeon must not hesitate to make a sufficiently long mid line incision and also, if necessary, to acquire still more room by cutting across one or other rectus muscle, usually the left The transverse incision described in the previous section may be entirely satisfactory As a rule, the intra abdominal approach will be through the gastro-colic omentum, but the growth of the tumour upwards and forwards may dictate the gastro-hepatic omentum as the better avenue At an early stage the splenic artery and vein should be exposed, ligatured and divided, after which there need be little fear of gross hæmorrhage, though all vessels seen must be carefully caught before being severed When the tumour is in the extremity of the tail, removal of the spleen will be almost a necessity, but even with a tumour further removed splenectomy will often facilitate the intervention When the pancreas with the tumour has been completely freed from its surrounding connections, it should be lifted well forwards into the wound so that the body of the gland may be clearly seen before being divided It is not necessary nor is it wise to put a clamp across the gland, which should be divided section by section, sutures being introduced and some tied before the division is complete The sutures may be of catgut or silk Needless to say, hæmostasis must be accurate and drainage must always be provided

Operation for removal of the head of the pancreas and for total removal of the gland.—If, after thorough preliminary examination, the surgeon decides that extirpation of the pancreas is feasible, the necessary intervention should be carried out in stages The first stage consists of gastro-enterostomy, ligature of the common bile-duct and cholecystgastrostomy The second is the removal of the pancreas, which necessitates excision of the loop of the duodenum The interval between the stages is usually about three weeks, but unless recovery after the first intervention is satisfactory it is not wise to proceed to the second stage At the first operation the incision must be in the middle line and of sufficient size to enable the parts to be carefully inspected, for the surgeon cannot decide by palpation alone whether the condition is operable If there are signs of dissemination, radical operation is out of the question It is sometimes recommended that the gastro-enterostomy should be of the *en Y* type, but this is not essential The union between the gall-bladder and stomach should be made well on the proximal side of the pylorus and with a large opening (*see* p 830)

At the second intervention which is made by re-opening the original incision the duodenum is divided just beyond the pylorus the proximal end being securely closed To expose the rest of the duodenum it is necessary to mobilize the hepatic flexure of the colon and draw it downwards At this stage it is well to divide the gastro-colic omentum over the whole extent of the pancreas Great care must be taken to avoid the middle colic and the superior mesenteric arteries The division of the distal part of the duodenum is made in its third part and the distal end is securely closed The mobilization of the pancreas with the tumour is best commenced by dividing the peritoneum along its lower border With the finger behind the gland it is lifted forwards so that the upper border with the splenic artery and vein can be defined These vessels are securely ligatured and divided If the whole gland is to be removed the tail is completely isolated drawn downwards and then lifted forwards and turned to the right The separation of the head can then be carried out partly from behind and partly from the outer side after free division of the peritoneum as it is reflected from the second part of the duodenum At the upper border of the head the common bile duct must be carefully isolated and if this has not already been done must be ligatured with chromic catgut or silk and divided The very close association of the portal vein and superior mesenteric vein and artery must be ever in the surgeon s mind and the vessels must be carefully separated from the gland The portal and mesenteric veins have large lumens and if some part of the wall is very adherent or even infiltrated it may be cut away the resulting defect in the vein being closed by a continuous suture of fine arterial silk The veins must be caught in light clamps before any part of their wall is excised otherwise very copious blood loss may occur in a short time The clamp should be a vascular clamp or a very light bowel clamp but not a crushing forceps The vena cava is in close relation to the back of the gland and can best be exposed and separated from the outer side If the tail of the gland is well away from the growth it need not be removed but the cut surface should be drawn together by suture It is unnecessary to attempt to implant this part of the gland into the bowel as was suggested by Coffey and carried out by Desjardins The space from which the head has been removed can be diminished by a few sutures between peritoneal edges but it cannot be obliterated and should always be drained (Fig 440)

This same type of operation has been employed in dealing with malignant growths of the ampulla of Vater with encouraging results *

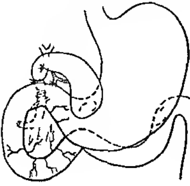
Where the growth cannot be removed biliary obstruction and itching due to the resulting jaundice may be relieved by cholecystgastrostomy

In inoperable cases Sampson Handley has implanted radon seeds into the mass with some success

Results—Of Finney s 17 cases 9 recovered and 8 all malignant

* Whipple Parsons and Mullins, *Ann. Surg* Oc 1935 cii, 763

cases with adhesions, died * He considers that the prognosis depends upon the situation of the growth, being more favourable in tumours in the tail of the pancreas than in those nearer the head, while if they are pedunculated the prognosis is still better Gordon Taylor s patient



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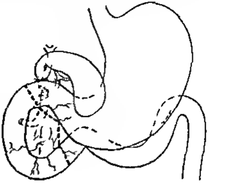

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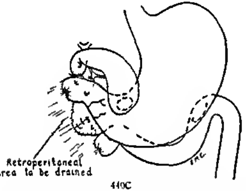


440C

Fig 440 — Excision of head of pancreas in two stages

A Gastro-enterostomy cholecystgastrostomy and div on and ligature of commo bile duct

B Excision of loop of duodenum with head of pancreas

C The cut surfaces of the pancreas have been sutured together and the ends of the divided portions of the duodenum closed by suture (Modified from Whipple Parsons and Mullins *Ann Surg* Oct 1935)

was alive and well for eleven years after removal of a massive carcinoma of the body of the gland Recurrence then took place, leading to death just over thirteen years after operation† In Sherren's case‡, a sarcoma of the head of the pancreas the patient was in good health eighteen months after operation

CYSTS

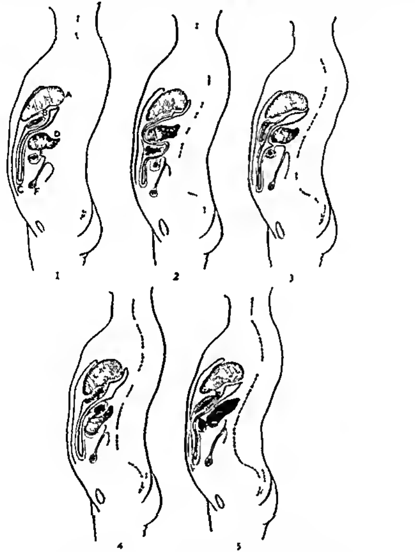
Cysts of the pancreas may be divided into *true cysts* (retention, cystic adenoma, hydatid) and *pseudocysts*, which are either inflammatory effusions into the lesser sac or collections in the peri-pancreatic tissues These pseudo-cysts sometimes attain a considerable size, and have given rise to many mistaken diagnoses

Cysts usually present between the stomach and the transverse colon, being covered by the gastro-colic omentum (Fig 441) Occasionally they displace the stomach downwards and present between the stomach and the liver through the gastro hepatic omentum If they arise from the tail of the pancreas they may grow into the mesocolon, either

* *Trans Amer Surg Assoc* 1910 xxviii 315
† *Ann Surg* July 1934 c 206 also *Brit Med Journ* 1942 ii 119
‡ *Lancet* 1911 i 1491

displacing the colon downwards or lying behind it Albert and Page report a case in which the cyst emerged through the foramen of Winslow

As a rule it is only the smaller pancreatic cysts that can be completely removed, but the question of operability cannot be determined until



1 2 3

4 5

Fig 441 —Diagram of pancreatic cysts showing different presentations.
1 Gastro-colic 2, gastro-hepatic 3 retrogastric 4 subcolic 5 retrocolic
A, Liver B stomach C omentum D pancreatic cyst E transverse colon F small intestine

the surgeon has the opportunity of making a complete exploration with the abdomen opened It is not entirely a question of size but of the fixity of the cyst to the surrounding parts and especially the nature of its attachment to the pancreas There can be no doubt that in the majority of cases drainage is all that is necessary and it is certainly much safer than total removal Nevertheless when there are few

adhesions or perhaps none at all, and the surgeon can explore the site of attachment at an early stage of the operation, there are some cases in which the cyst may be safely enucleated from the pancreas and there are others situated near the tail of the gland in which the cyst may be removed together with a part of the gland In a series of 46 cases reported (to April, 1930) from the Mayo Clinic, 7 were enucleated or excised and 33 drained, and 6 were partially excised and drained If the cyst cannot be completely removed, it is often possible to excise a considerable portion, but in doing this the surgeon must be sure that he leaves enough cyst wall to attach to the parietes for drainage In all cases where drainage is to be carried out, the interior of the cyst should be gently explored, for sometimes masses of débris may be removed and will facilitate recovery But manipulations inside the cyst must be gentle, as otherwise serious hæmorrhage may be set up and may be difficult to control If the cavity is very large or there is hæmorrhage, it may be wise to pack lightly with gauze In any case a large tube will have to be left *in situ* For the pseudo-cysts drainage is all that is necessary

Technique.—The abdomen is opened by a supra-umbilical median incision In most cases it will be found best to expose the cyst by dividing the layers of the gastro-colic omentum The general peritoneal cavity must be shut off with flat swabs, as the contents of the cyst might irritate the peritoneum or at least the fat in the abdominal wall in the event of an accidental rupture The cyst having been exposed, its relations and attachments must be investigated There are three methods of treatment—complete enucleation partial removal with drainage, and drainage after suturing the cyst wall to the parietes (marsupialization) There is no doubt that of the three, enucleation is the most satisfactory, as it generally allows immediate closure of the abdomen Treatment by drainage may be prolonged Unfortunately there are very few cases in which removal is feasible If enucleation be decided upon, it is better to separate the attachments without evacuating the cyst-contents, but great care is necessary to avoid rupture If the cyst-wall is thin, and therefore likely to give way, and there seems a good prospect of enucleation, the cyst should first be emptied through a cannula before the deep separation is done The cyst is enucleated by blunt dissection often considerable hæmorrhage is encountered The principal danger is injury to the superior mesenteric artery, an accident which is almost certain to prove fatal Injury to the splenic artery or to the arteries of the stomach is less serious, as these organs have additional supplies

After removal of the cyst, the area must be examined in a good light, any bleeding-points controlled, and the pancreas sutured with catgut if it is lacerated It may be necessary to use gauze packing to control oozing from the cyst-bed, but this should be avoided whenever possible as it encourages subsequent fistula If gauze must be used, it should be wrapped in rubber tissue and a tube should be used in addition, to provide drainage after the gauze is removed

If enucleation is considered inadvisable the cyst wall is brought up to the abdominal incision and sutured to the parietal peritoneum If it will not reach up to the parietes the cyst should be emptied through a cannula when it will be found easier to bring the wall forward An incision is made into the cyst either at once or subsequently (Gussenbauer s two stage operation) and a large drainage-tube inserted In pseudo-cysts it is only necessary to establish drainage An anterior incision over the most prominent part of the swelling is usually employed but when the cavity is very large and especially when it extends towards the left a second independent drainage opening may greatly facilitate recovery The latter should be made in the left subcostal space near the border of the erector spinæ As the fluid from these cysts at least from the true cysts may irritate or even digest the skin a protective dressing of white of egg is a wise precaution

After treatment—The tube can usually be removed in two or three weeks by which time the discharge will probably be much lessened Thereafter it may quickly cease or may persist for so long as to be very troublesome In that case special consideration must be given to diminishing secretion and inducing the track to close A strict diabetic diet has been found effective in reducing the amount of discharge and the addition of much fat to the diet has the same effect Wohlegemuth advises bicarbonate of soda in large doses Irritation of the skin may be mitigated by drying it and painting with white of egg or milk or 2 per cent hydrochloric acid

Results—Cases treated by drainage may be expected to make a good immediate recovery with a mortality of about 5 per cent but ultimate recovery is often slow and there is a residue of patients with persistent fistulæ and a few develop diabetes

Complete extirpation can be performed in only very few cases and carries a mortality of about 20 per cent

INFECTIONS

Inflammations of the pancreas excluding the rare cases due to such disorders as mumps typhoid fever tuberculosis and syphilis result from coincident infections of the bile-passages *It follows that* while in some cases of acute and subacute pancreatitis a direct operation may be done on the gland it is often necessary to combine this with some procedure designed to counteract the infectivity of the bile In chronic pancreatitis operative treatment is mainly directed to the gall bladder and biliary ducts

Although it is customary to speak of acute pancreatitis as hæmorrhagic gangrenous or suppurative these are not clear-cut clinical types and their main features may overlap to a considerable extent As met with in practice the cases usually range themselves in one or other of three groups (1) the very acute fulminating varieties which may turn out to be hæmorrhagic or gangrenous Death often occurs within

18 hours and autopsy may disclose diffuse hæmorrhagic infarction or infective necrosis of the greater part of the gland Obviously there is little that can be done in such very acute conditions, and it is doubtful if opening the abdomen adds to the chance of recovery If a case which begins as a major abdominal catastrophe does happen to show signs of recovery, there may be a stage at which drainage of the gall-bladder or an incision into the extra peritoneal tissues may help (2) The next group is an acute variety but of moderate severity in which spontaneous recovery may occur either with or without the formation of localized abscesses (3) In a third group in which pancreatitis is found usually unexpectedly on opening the abdomen the symptoms are those of an accompanying acute gall bladder infection, often with suppurative cholecystitis

Surgeons disagree profoundly on the place of operative interference in acute pancreatitis In my opinion it is wiser to operate (*a*) lest there be some mistake in diagnosis, for acute biliary infections, leaking ulcers and even high intestinal obstructions have all been mistaken for pancreatitis, (*b*) because drainage of the biliary system is a valuable method of influencing the course of the disease If the case is not seen until the acute symptoms have settled down and the patient is improving in every respect, operation is not indicated Sometimes improvement occurs up to a point and is then arrested or followed by pyrexia and other signs of recurrent inflammatory trouble with evidence of pancreatic insufficiency In these circumstances a lump may be detected about the situation of the gland This usually means that there is some necrosis with abscess formation Sometimes these abscesses find their way into the stomach or duodenum but if this does not occur they should be explored In these circumstances the wisest course is to be content to open and establish drainage, sloughs can be more safely removed after the drainage track has been shut off

Epitome of treatment.—Most benefit follows free external bile drainage, and many cases are cured by this alone When the gall-bladder cannot be easily reached for this purpose, it may be possible to open the common duct The gall bladder must never be removed, *as it may be invaluable at a later stage for cholecystenterostomy* Incision of the substance of the pancreas itself is of doubtful value, but should it be considered advisable, a blunt dissector should be employed for the purpose, owing to the risk of severe hæmorrhage If there is much effusion in the flanks, and evidence of retroperitoneal involvement, as shown by surface discoloration (Grey Turner's sign), separate incisions must be made in either loin to open up the retroperitoneal space for drainage When there is a definite localized mass the surgeon may find a considerable retroperitoneal collection, which may be drained from the front When the case is of longer duration and the symptoms indicate sloughing of a considerable part of the gland, the sloughs must be sought and removed During convalescence the surgeon must be on the watch for signs of pancreatic insufficiency

Technique —The abdomen is opened in the middle line above the umbilicus or through a vertical rectus incision The peritoneum nearly always contains fluid which may be clear straw-coloured blood stained or slightly turbid The diagnosis is confirmed by the presence of fat necrosis which is often the first abnormality recognized The biliary tract is then examined the gall bladder and common bile-duct being palpated for stones In most cases a cholecystostomy is all that should be done The patients are nearly always far too ill for measures requiring much manipulation and unless stones in the common duct are easily accessible they should be left for a future intervention The one essential is to establish external biliary drainage

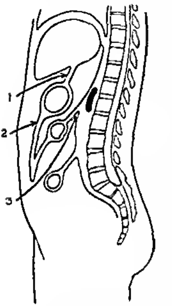


Fig 442 —Lines of approach to the pancreas

If it is considered necessary to expose the pancreas there are three lines of approach (1) through the gastro-hepatic omentum (2) through the gastro-colic omentum and (3) through the transverse mesocolon (Fig 442) Of these the last owing to risk of injuring the middle colic artery in swollen tissues is not to be recommended The approach through the gastro colic omentum is the better of the other two The pancreas is exposed through the lesser sac after shutting off the general cavity of the peritoneum with moistened gauze swabs A certain amount of blood stained exudate is usually found around the gland Punctures are made into the pancreas with a blunt instrument and the organ is drained by tube or gauze tamponnade

There has been some difference of opinion on the advisability of attempting to drain the pancreas directly in the acute stage before necrosis or pus formation Probably it is more a question of the relief of tension by incising the coverings of the gland

The general peritoneal cavity need not be drained unless the fluid is obviously infected Nevertheless when there is a great deal of fluid which is flaky and perhaps offensive a tube from the pelvis through an independent opening above the pubes may be a comfort both to patient and surgeon

If the pancreatic inflammation goes on to pus formation an abscess will form immediately around the pancreas or it may pass towards the left lumbar region or upwards to the left subphrenic space If the pus cannot safely be reached from the original incision separate drainage must be provided in the flank or subcostal region (Fig 443)

Complications and sequelæ—*After the immediate danger of shock* is passed sepsis and hæmorrhage are the chief complications With

sloughing of the pancreas and with abscess haemorrhage is a serious and not unusual feature in the course of convalescence The large arterial branches along the upper border of the pancreas, mostly derived from the splenic artery, are usually the source The splenic and mesenteric veins may also become thrombosed, with fatal results Large portions of the gland may necrose and be discharged as sloughs, sometimes only the head of the gland remains In these cases and even when there is much less destruction, pancreatic insufficiency becomes a serious menace Continued slight vomiting is always a very suggestive symptom and, later wasting, air hunger and cyanosis are pathognomonic To anticipate and correct this condition care must be taken with feeding, and the secretion of the gland must be stimulated by the

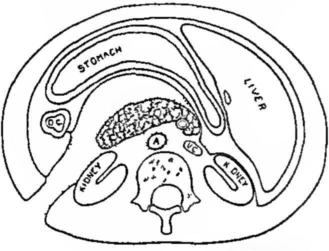


Fig 443 —Drainage of pancreas through incision in left flank
(After A Dickson Wright modified)

exhibition of weak acids, while an attempt should be made to supply the deficient ferments by giving extracts of the gland by mouth Estimation of the serum amylase and lipase is a guide to the extent and progress of the deficiency In the later stages, persistent fistula or diabetes may occur The treatment of fistula is discussed on p 866

Relapses after operations for acute pancreatitis.—The majority of cases that survive operations for acute pancreatitis appear to be completely cured Early recurrence may follow insufficiently prolonged drainage but the condition may return after months or years Recurrences are usually much less severe than the primary condition and normally recover without operation A proportion develop chronic pancreatitis or diabetes, so that the prognosis after operation must be guarded Recurring attacks of pain are probably due to overlooked gall stones or to concomitant duodenal ulcer Sometimes a cyst develops as a late sequel

Results.—The mortality in cases operated upon during the acute

phase is between 50 and 60 per cent When intervention is delayed the mortality among those who survive and require operation is from 15 to 20 per cent

CHRONIC PANCREATITIS

It may be agreed that excluding cases due to certain specific infections to pancreatic lithiasis or to direct extension from ulcer of the stomach or duodenum chronic pancreatitis results from some pre existing and coincident infection of the gall bladder or bile ducts It follows that in order to obtain a cure treatment must be directed to remedying the biliary infection This is effected by removal of the cause such as gall stones and by biliary drainage (for two to three months as a minimum) The simplest method is by cholecystostomy but if the common bile-duct becomes occluded a more or less permanent fistula may result which is not ooly a great inconvenience but also deprives the patient of the digestive value of the bile To overcome the difficulty Winiwarter in 1880 did the first anastomosis of the gall bladder to the intestine and at the present day this is the accepted treatment in cases of well established non malignant pancreatitis affecting the head of the organ Four sites have been used for the anastomosis—(1) the stomach (2) the duodenum (3) the jejunum (4) the colon Anastomosis with the colon may be dismissed as inadvisable if any of the other three courses is available for the contents of the large bowel have a much higher degree of infectivity than the other parts of the alimentary canal Cholecystgastrostomy is usually easy and the introduction of bile into the stomach does not appear to cause inconvenience Cholecysto-duodenostomy would seem to be the ideal procedure as the bile enters the intestinal tract approximately at the spot where it should enter It is not a very difficult operation if the duodenum can be brought well forward In some cases it may be necessary to adopt Kocher s method of mobilizing the duodenum which consists in making a vertical incision in the peritoneal reflection just to the outer side of the duodenum and raising it forwards by blunt dissection with the fingers In cholecysto jejunostomy a point in the jejunum some 14 in from the duodeno-jejunal flexure is chosen and a loop brought across the abdomen below the omentum and upwards in front of the hepatic flexure of the colon Anastomosis is easy but to prevent delay in the passage of the intestinal contents and also to lessen the risk of infection it has been suggested that the operation should be sopplemented by an entero anastomosis between the afferent and efferent limbs of the loop Details of these operations will be found on p 830 but it may be said here that of the four methods anastomosis between gall bladder and stomach is generally adopted If the patient is very ill or when there is jaundice or many adhesions the anastomosis may be made in two stages As a first stage external drainage of the gall bladder is secured and if the improvement in the condition justifies further intervention the

gall bladder is later separated from the parietes and united to stomach or duodenum

In certain cases the gall bladder may not be available—e g where it has been removed at an earlier operation There are then two alternatives (1) to anastomose the common bile duct to the duodenum (choledocho enterostomy) or (2) to arrange for prolonged drainage of the common bile-duct (choledochostomy)

Mallet Guy states that the maximum amount of change in chronic pancreatitis is limited to the tail of the gland and for that reason recommends hemipancreatectomy He has reported four cases in which the results were satisfactory The technique is that described in connection with the treatment of hypoglycæmia (p 858) The difficulty of clearing the splenic vessels is emphasised Drainage is always employed and discharge of secretion may continue for some weeks

Results —Cholecystenterostomy for chronic interstitial pancreatitis carries an immediate mortality of about 10 per cent The subsequent health of the patient largely depends on the amount of damage sustained by the gland as the result of the inflammatory process

Pancreatic Lithiasis

This condition is very rare It occurs more often in men than in women The calculi are usually multiple and vary from mere sand to the size of a walnut They are not facetted and are usually light in colour Though often found near the head of the gland they may be scattered throughout its substance There is often fibrosis either of the whole gland or in the vicinity of the calclus and this may make it difficult to detect the stones by palpation In the few cases recorded the calculi have generally been situated in the head and have been removed by the transduodenal route exposing the ampulla of Vater through an incision in the second part of the duodenum The opening of the ampulla is slit up and the stones are removed from the duct of Wirsung with fine forceps or a scoop In other cases a direct incision has been made into the gland and the calculus removed When this has to be done drainage by tube should be provided In most cases there is associated disease of the biliary tract in the form of calculi either with or without infection For this reason a careful examination of the gall bladder and ducts must always be made and any pathological condition appropriately dealt with

There is often associated fibrosis of the gland which may make it difficult to palpate the stones In such cases drainage of the biliary system is indicated

The Pancreas and Gastrectomy

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The Pancreas and Gastrectomy

The pancreas may form the base of an eroding gastric ulcer, and a crater may be left exposed when the stomach is separated from the gland in the course of gastrectomy It is not necessary to excise

such craters but they should be lightly seared over with the cautery or swabbed with pure carbolic

Excision of a superficial portion of the gland may be necessary in the operation of gastrectomy for cancer The wound so made should be drawn together by catgut sutures or should be covered by adjoining tissue or omentum and a track to the surface provided by a rubber drain Gauze must not be left in contact with the gland unless for the purpose of staunching otherwise uncontrollable oozing for when removed it is apt to tear the surface and to encourage the escape of pancreatic secretion

Pancreatic Fistula

This condition may result from direct laceration whether from injuries like gunshot wounds or such trauma as is necessarily inflicted during the course of the operative removal of tumours It may also follow the drainage of cysts or *inflammatory collections about the* gland Since the escaping juice is not activated by enterokinase it does not digest the tissues though it usually produces very troublesome irritation of the surrounding skin When infected with pyogenic organisms it may cause severe general symptoms After trauma the discharge may be expected to cease in three or four weeks as the healing process proceeds but in pathological states it may persist for months or years Generally speaking little can be done to deal directly with the cause except in those cases which follow pancreatitis when the removal of a slough may do much to bring the trouble to an end The best line of treatment is continuous suction which may be carried out by a water pump of the Sprengel variety or an electrically driven pump The orifice of the fistula may be covered by a special cap or a catheter may be introduced to which the suction apparatus is attached In either case it is essential that the suction should not be too powerful or pain or hæmorrhage may result When the discharge appreciably diminishes the suction may be interrupted for some hours at a time or for a day or two when healing may follow

In intractable cases radium introduced into the track may set up a healthy reaction and bring about cure

Should the fistula become chronic in spite of treatment its management will depend upon the underlying condition If the operation has been for a cystic condition (true cyst) it probably means that this has not contracted and remains as a cavity of considerable size In these circumstances the remains of the cyst may be anastomosed to the stomach or the upper intestine whichever is more conveniently situated for the purpose If on the other hand there is no cavity but merely a track this may be dissected out from the parietes and implanted into the stomach or intestine in much the same way as is sometimes employed for chronic biliary fistula (see p 843)

CHAPTER XVIII

OPERATIONS ON THE SPLEEN

By G. GREY TURNER

Anatomical and physiological observations.—This organ lies on the left side, hidden by the 9th 10th and 11th ribs and with its long axis in the line of the tenth It must be remembered that the lower part of the pleural cavity, and to a varying extent the lung are interposed between the spleen and the surface of the body Its protected situation means that if palpable below the costal margin it is probably pathologically enlarged It is important to remember how closely the cardiac end of the stomach nestles into the hollow in front of the *hilum of the spleen and the way in which the tail of the pancreas* abuts on the inner surface of its lower pole Both these organs have been injured during the operation of splenectomy, and they must be *identified in order to be avoided The close relationship* of the outer surface of the spleen to the under aspect of the diaphragm makes it apt to adhere to that structure Relative to the size of the organ, the splenic vessels are very large, and in pathological states they may become enormous The veins always appear to be unusually friable The principal vessels lie in the lieno renal ligament which connects the organ to the anterior surface of the left kidney, while the gastrosplenic omentum carries smaller branches of the splenic vessels—the vasa brevia—which pass to the cardiac end of the stomach (Fig 448, p 876)

Accessory spleens are quite common and may be multiple They are seldom larger than hazel nuts and usually lie between the layers of the neighbouring mesenteries On very rare occasions accessory spleens have attained such a size as to produce symptoms and justify removal

The size of the spleen its sheltered position, its special structure and vascular arrangements and the variations in size which occur during normal health all suggest that the organ subserves some important function Nevertheless, the continued observation of those in whom the normal spleen has been removed for injury go to show that at least the organ is not indispensable in the economy of the body

In adult life it has to do with the destruction of red blood cells, probably those that are worn out, with the disposal of particulate matter and with the metabolism of iron It seems also to be a container for a reserve of blood, and in some obscure way appears connected with the blood platelets It probably plays the part of a link in a physiological chain but it is not an indispensable one Many spleenless people are perfectly well, and appear to be admirably adapted to their everyday environment, even when disturbed by intercurrent disease

Splenectomy for injury —Operative interference for injuries and diseases of the spleen is almost limited to removal The spleen may be injured by stab wounds and crushes In civil practice crushes such as are likely in motor car accidents are the commonest cause Sub capsular tears may give rise to late hæmorrhage some few days after the injury In all forms of injury hæmorrhage is the main cause of death and as the structure of the spleen makes suture almost im possible splenectomy is the operation of choice (except in some stab-wounds in which it may be justifiable to attempt conservative surgery) Even in civil life and in the very best circumstances of early and efficient surgical treatment the mortality is high In warfare com plications are often present especially wounds of the stomach or intestines and these materially increase the death rate (p 670)

Splenectomy for disease —*Malaria* —The enlarged spleen has been removed on many occasions for this was one of the earliest diseases for which splenectomy was performed When the bulk of a chronic malarial spleen renders it an inconvenience and a danger splenectomy may be considered In the absence of adhesions the operation is reasonably safe otherwise the inevitable hæmorrhage makes it exceedingly dangerous

Splenic anæmia —In this disease characterized by an enlarged spleen leucopenic anæmia and spontaneous hæmorrhages especially hæmatemesis splenectomy has proved of definite value It is generally held that there is some relation between the platelet count and the prognosis in splenectomy for this disease When the count is high (250 000 to 400 000 per c mm is normal range) there is more risk of post-operative thrombosis in the splenic and portal veins

Banti s disease —This is probably only a later stage of splenic anæmia The results of splenectomy have been very encouraging In the later stages when ascites has supervened the operation has been less successful but if combined with omentopexy it may confer great benefit

Acholuric or hæmolytic jaundice —Considering what is known of the functions of the spleen splenectomy should have great value in diseases characterized by increased blood destruction, and in hæmolytic jaundice both congenital and acquired many successful splenec tomies have been recorded The operation has a comparatively low mortality and is followed by rapid disappearance of jaundice with decrease of the anæmia and blood fragility It is most important not to operate during the crises which are characteristic of this disease Pigmented gall stones are often present and should be removed at the time of the splenectomy or subsequently It is also essential that splenculi should be sought for and removed as their subsequent hypertrophy may account for some recurrences

Purpura hæmorrhagica —The thrombocytopenic type of purpura is now recognized as one of the indications for splenectomy in which the results have been very satisfactory It is essential that the opera tion should not be carried out during an acute phase Blood trans

fusion should always be done once or twice before the operation and the platelet count should be watched

Egyptian Splenomegaly —The ætiology of this condition is very doubtful but many cases are treated by splenectomy with remarkable immediate success and sometimes lasting benefit

Abscess and cyst may sometimes require splenectomy rather than drainage or local incision On rare occasions *new growths* like carcinoma or sarcoma of the organ may be found sufficiently localized for removal by splenectomy

Wandering spleen cannot be cured by splenopexy with any certainty and removal is necessary When complicated by torsion of the pedicle the operation becomes an emergency Whenever possible a careful blood examination should precede splenectomy tragedies have followed neglect of this precaution for the leukæmic spleen removal of which is contra indicated may wander

Splenectomy may also be the only possible method of dealing with *aneurysm of the splenic artery* or *thrombosis of the vein*

Whenever surgical intervention is contemplated in pathological states of the spleen it is essential that physician and surgeon should co operate in determining not only the indications but the correct stage of the disease at which intervention should take place

Quite apart from conditions in which splenectomy may be definitely indicated there are circumstances in which removal facilitates other surgical procedures For instance I have often removed the spleen with the stomach in difficult gastrectomy for extensive carcinoma Similarly its ablation may facilitate or even render possible the removal of retro peritoneal tumours or cysts originating about the tail of the pancreas

Preparation —This largely concerns the degree of anæmia present In bad cases blood transfusion may be essential before during and after the operation Even in the most favourable cases the surgeon should be prepared to transfuse should some unexpected necessity arise It is essential that the intestine should not be distended and the patient should be accustomed to the passage of the stomach tube Radiotherapy is sometimes employed as a means of reducing the size of the organ but should be discontinued at least a fortnight before operation

Technique —The operation of splenectomy may be very simple or may present many difficulties The latter almost entirely concern the management of adhesions and the real danger is hæmorrhage Both the spleen and its pedicle as well as the surrounding adhesions are easily torn and the surgeon must be prepared to exercise great care and gentleness Most operators gain increasing respect for splenectomy the oftener they are called upon to perform it When the organ can be lifted out of the abdominal incision the operation may be one of the easiest and safest in surgery But when there are diffuse firm adhesions the bleeding is often terrific and the operation most dangerous In fact in many of the latter cases it would probably be

wiser to abandon the attempt to remove the spleen and to be content to diminish its activity by ligaturing as much of the pedicle as can be safely reached The operation of splenectomy consists of five steps—(1) *incision* (2) mobilization and delivery which may involve freeing many adhesions (3) securing the pedicle (4) hæmostasis of the splenic bed (5) closure of the wound

The incision —The principles guiding the surgeon in the choice of

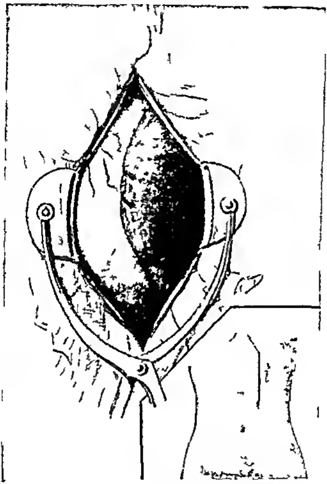

Fig 444 —Splenectomy incision and exposure

the incision are to make one free enough to give adequate exposure so that the separation of adhesions the delivery of the organ and the *securing of the pedicle* can be done without embarrassment It must also be large enough to permit thorough examination of other organs especially the liver gall bladder and stomach It is a great advantage to be able to separate the adhesions under direct observation The incision giving the best access is a vertical one through the outer third of the left rectus and extending from the left costal margin to or

below the level of the umbilicus This incision must go right up to the costal margin and must extend to three fingers breadth below the caudal end of the spleen quite irrespective of its total length The rectus muscle is separated in the direction of its fibres and the abdomen opened through the posterior sheath just as in the right sided vertical incision for exposure of the gall bladder If more room is required the skin and anterior rectus sheath can be further divided by an oblique extension passing upwards and inwards from the upper end

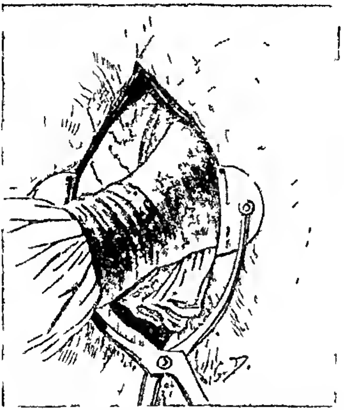

Fig 445 —Splenectomy freeing the spleen on its outer surface

of the vertical incision just below and parallel to the costal margin (Fig 444) It is rarely necessary to cut across the fibres of the rectus which can be further retracted after this oblique incision has been made The incision is held open by a self retaining retractor and a general examination of the abdominal organs made The removal of the spleen is then methodically carried out

When the spleen is free from adhesions the organ is delivered from *the abdomen before the pedicle is dealt with* When there is only moderate enlargement and no adhesions it is only necessary to slip the hand over the outer surface and to lift it forward (Fig 445) The region of the hilum must always be very gently handled as the vessels are exceptionally delicate and may readily be torn There are some

few vessels—the vasa brevia—passing directly from the stomach to the spleen in the gastro splenic omentum and this must be first dealt with It is picked up in sections with its vessels and either divided between ligatures or artery forceps are left on the splenic side This structure having been divided the pedicle proper—the lieno-renal ligament containing the splenic artery—comes into view and should be thoroughly exposed and ligatured in sections commencing from below and working towards the upper pole Before applying

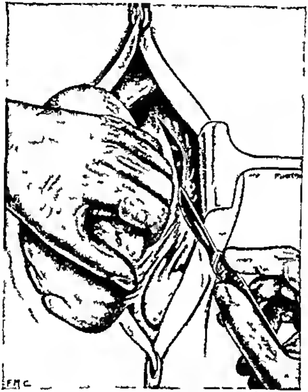

Fig 446 —Exposure of splen c pedicle from behind
(After Rodney Maingot)

forceps or ligatures the position of the tail of the pancreas must be ascertained for when the lieno renal ligament is short it may be close to the spleen In these circumstances it is better to approach the vessels from behind by turning the spleen over to the right and incising the posterior layer of the ligament (Fig 446) If the pancreas is then seen it can be gently thrust aside by gauze stripping In very exceptional cases or when there is great urgency the pedicle may be dealt with by a single encircling ligature but the best plan is to clamp it in sections and to divide it between the clamps If the pedicle is not caught on the spleen side there is great hæmorrhage Another plan is to clamp a section of the pedicle on the spleen side and to surround the proximal part with a ligature which is securely tied

before the intervening portion is divided This process is carried on until the whole of the pedicle is secured Great care must be taken not to puncture any of the vessels in passing the ligatures Interlocking ligatures are not necessary and had better be avoided

After the spleen is cut away, the pedicle should be carefully inspected Vessels in any part which are very prominent, or in which there may be any risk of retraction, must be separately caught on the cut surface and surrounded by independent ligatures The best material is chromicized catgut, size No 1 When the pedicle is absolutely dry it may be allowed to drop back into the abdomen In cases free from adhesions, no hæmorrhage is likely from the spleen bed, and the abdominal wall may be completely closed But if any adhesions have been separated it is wiser to bring a softened rubber tube or rubber strand from the spleen bed, simply to provide a track so that the surgeon may be made aware of any unexpected hæmorrhage

When there are adhesions, the surgeon may endeavour to insinuate the hand gently between the outer surface of the spleen and the parietes When the adhesions are very soft, it may be possible to lift the spleen forward and to turn it over inwards without undue risk Such adhesions will, of course, tear and retract without much bleeding, but on the other hand very considerable oozing may result After delivering the organ a very large hot moist gauze pack should follow the hand and be thrust into the bed from which the spleen has been lifted The process of separating these soft adhesions and delivering the spleen should not be too deliberate, as severe bleeding may occur in a very short time and occupy the space in which the spleen lay The pedicle is then treated as described After the spleen has been cut away, the gauze pack is gently withdrawn During this stage of the operation, the incision is held well open while the stomach and colon are drawn gently to the right and downwards As the pack is withdrawn, the splenic bed must be carefully inspected for bleeding-points For this purpose the reverse Trendelenberg position and a headlight are both very useful Any bleeding-points may be caught in long clips and independently tied, or they may be occluded by suture, which may pass from one to another if not too far apart, *or silver clips may be clamped on each point with a special instrument* Should it be impossible to stay all bleeding in this way, then it is necessary to pack a gauze strand of moderate size into the spleen-bed against any oozing areas The gauze leaves by the lower angle of the wound and is protected from contact with the viscera by strands of rubber tissue, it should not be removed sooner than four days and even then it may have to be taken out by degrees to avoid the risk of restarting the bleeding When there is no question of hæmorrhage the incision is usually completely closed, but should there be any doubt on this point it is much better to bring a rubber tube or strand from the splenic bed out through the incision Should reactionary hæmorrhage occur, the blood will then readily find its way into the dressings, thus establishing the diagnosis at once

The closure of the incision must be carefully carried out in layers with the addition of through and through sutures of silkworm gut every one or two inches Disruption of the incision has not been uncommon after splenectomy

In cases of *splenic anæmia* of long standing the adhesions are often so numerous and so strong that it is impossible to separate them in the way mentioned If there is difficulty in delivering the spleen in consequence an extension should be made from the middle of the vertical incision transversely through the outer half of the rectus muscle and back into the left loin which it should reach just below the costal margin (Fig 447) The T shaped incision thus made gives an exposure which is sufficient to deal with any combination of circumstances ever likely to be met with and it is never necessary to divide the ribs or to turn up a flap from the costal margin With this additional exposure strong adhesions may be clamped and divided under the guidance of the eye or they may be divided while at the same time the hæmorrhage is arrested by the diathermy knife Sometimes the organ is felted to its bed and has to be literally dug out In cases of this kind if it is impossible to control the bleeding efficiently the surgeon must not persevere in a foolish attempt to remove the spleen at all costs It may be feasible to expose and ligature some part of the pedicle in the hope of thus putting as large an area of the spleen as possible out of action and this plan has been proposed as an alternative to splenectomy in difficult cases

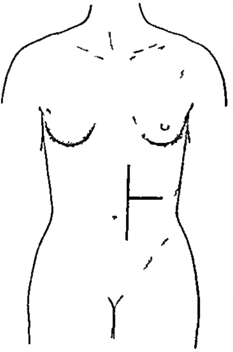
Fig 447 —Incision for difficult splenectomy

Bloodless splenectomy —It has been suggested that ligature of the splenic artery as a first step may render this operation practically bloodless Only when the spleen is free from adhesions and can be lifted out of the incision can the pedicle be exposed at an early stage and in such cases the operation presents so little difficulty that with ordinary care it can always be practically bloodless In the very adherent cases in which preliminary ligature of the artery might be most helpful the serious hæmorrhage occurs while the surgeon is carrying out those steps which must precede the exposure of the pedicle For these reasons this method is not likely to be so successful as it

sounds It may be well to mention here that pictures in works of surgery showing this operation are often extremely misleading

Splenectomy combined with omentopexy.—Where there is ascites with marked cirrhosis of the liver (advanced Banti's disease) it is always worth while, and in fact essential to attach the omentum to the posterior surface of the abdominal wall over as wide an area as possible If the condition of the patient permits the complete technique for omentopexy should be carried out (*see* p 778)

Splenectomy combined with the removal of other viscera.—When splenectomy is required as part of the operation of gastrectomy or removal of the splenic flexure of the colon or nephrectomy it is much simpler to remove the whole organ than to attempt merely to take away the involved part If partial removal is adopted there is great difficulty in controlling the hæmorrhage without any compensating advantage In performing total gastrectomy it often facilitates the operation to remove the spleen with the stomach even if it is not involved There is less trouble with hæmorrhage than if the vasa brevia are separately dealt with Dislocation of the spleen from its bed very much facilitates the mobilization of the fundus and cardiac end of the stomach

Comments.—In some cases of long standing splenic anæmia the abdominal wall is very vascular and there may be quite serious hæmorrhage when the rectus muscle is incised In these circumstances the diathermy knife may be used but it may not suffice to stay the bleeding In this eventuality, a continuous catgut suture, including all the structures but the skin may be run along either side of the incision and when drawn tight will usually arrest the hæmorrhage So much blood may be lost in opening the abdomen that blood transfusion at this stage may be necessary For the removal of the ruptured spleen an oblique incision a finger s breadth below the left costal margin and extending from the xiphisternum back into the flank gives an excellent exposure It is in long standing cases of splenic anæmia that most difficulty from adhesions is to be anticipated The surgeon must be provided with adequate assistance, and his armamentarium must be equal to any call, which will perforce be sudden Patients of this type should be blood grouped before the operation and a suitable donor or a store of blood should be in readiness In some cases the adhesions contain vessels of considerable size, mostly veins, but occasionally arteries The vessels of the pedicle may be atheromatous or unusually friable, and it may be difficult to get a good hold for the ligatures

In a valuable and most useful paper on the Removal of Large Spleens * A K Henry points out that to deliver the spleen from its bed it is necessary to bring the head out first, by inserting the hand between the viscus and the diaphragm (Fig 145) The novice must resist the temptation of trying to withdraw the spleen by pulling on its tail †

* *Brit Journ Surg* 1940 xxvii No 10? p 464

The greatest care must be taken in delivering the spleen through the incision for the purpose of exposing the posterior surface of the pedicle. If the organ is large and heavy or the pedicle short, gentle handling is necessary to prevent any sudden pull rupturing the pedicle.

The pedicle can only be properly and safely exposed by systematically dividing the structures which obscure it. Very often the left edge of the great omentum is adherent to the tail of the spleen. There may also be a fat laden fold of peritoneum in front of the gastro-splenic omentum or lesser pedicle (Fig. 448). These structures all contain vessels which, if torn, bleed furiously, and the only safe rule is to catch them in artery forceps or to ligature them before division. The late Sir David Wilkie was accustomed to say that all vessels near the spleen should be ligatured at sight, and with vessels that are so large and so

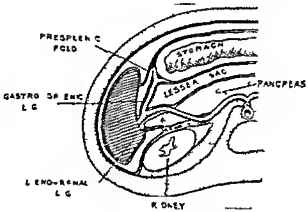

Fig. 448.—The splenic pedicle, showing pre splenic fold and relation of tail of pancreas.
(After A. K. Henry)

friable this is a good rule. If the parts to be ligatured are caught in artery forceps they ought to be tied at once, as the drag of the forceps or any accidental pull may tear away the vessels in their grasp, with great detriment and annoyance. Vessels that are clearly seen may be surrounded by ligatures passed on an aneurysm needle or a transfixion needle, but no instrument should be blindly thrust through these vascular tissues, as a punctured vessel may be a source of great trouble.

The close relation of the spleen to the diaphragm has important practical implications. Adhesions fixing the spleen are for the most part attached to the cupola, and bleeding areas are usual on its under surface. In efforts to catch and to tie such areas the diaphragm is easily torn or otherwise damaged, for it is only a thin structure. Vessels that cannot be easily caught in artery forceps should be underrun and ligatured, but the needle must not penetrate deeply or the pleura may be punctured. Large spleens probably support that half of the diaphragm to which they are in relation, and the loss of this support after splenectomy may interfere with the movement and the position

of the diaphragm and predispose to chest complications To mitigate these troubles A K Henry tried introducing an inflated rubber balloon into the space previously occupied by the spleen A limited trial convinced him of the value of this plan for the convalescence of the patients in which it was used was smoother than others

It is well to remember that many cases of hæmolytic jaundice harbour gall stones which may be removed at the same time if the splenectomy has been easy When as often happens the stones are soft and small it is only necessary to carry out cholecystendysis As a rule it is much better to deal with them at a subsequent operation

Complications and after-treatment—The immediate complications of the operation are shock and hæmorrhage It must be remembered that in many cases these patients are very poor operative risks and they may be expected to suffer more from these complications than in many other abdominal diseases When the condition demanding the operation is not associated with any special tendency to hæmorrhage severe bleeding is a reproach on the conduct of the operation but the fact that it has occurred in careful hands emphasizes the extreme need for care in splenectomy

In the few hours immediately succeeding the operation there is often a considerable amount of hæmorrhagic oozing indicated by the seepage of blood into the dressings or by a steadily rising pulse rate with pallor and restlessness It ought not to be serious and is probably best treated by blood transfusion and a small dose of morphia with the idea of keeping the patient and the circulation as quiet as possible Really alarming hæmorrhage probably means that a vessel has not been properly secured or that considerable bleeding is going on from a multitude of small points In either case the only course is to re-open the wound and to endeavour to secure the bleeding points under the guidance of the eye or to pack the cavity from which the spleen has been removed with gauze either plain or soaked in one of the hæmo static sera Again blood transfusion will be essential and may have to be repeated In these circumstances it may not be wise to spend time in accurate re-suture of the wound which should simply be drawn together with a few through and through sutures careful secondary closure can then be carried out when the gauze is removed If the pancreas has been injured during the operation local inflammatory mischief with fat necrosis may follow and may either spread causing peritonitis or produce a pancreatic fistula Because of these sequelæ it is essential to provide drainage to the surface whenever there is any question of damage to the tail of the pancreas When the usual anterior approach has been employed the drain should be brought to the surface by the shortest possible route through an independent incision in the flank

There is a tendency to left sided pulmonary complications in the first forty eight hours A slight basal pleurisy has often been noted about the fourth day and may be followed by effusion but there may be pulmonary collapse or pneumonia As a rule these conditions clear

up without trouble, but occasionally a septic element has evidently been introduced and empyema has resulted

Hæmatemesis may take place within a few hours of the operation or in the course of the first day or two or even after some weeks In these circumstances the bleeding is often profuse and alarming, and has been the cause of fatalities In this emergency treatment is almost limited to blood transfusion To guard against recurrence, injection of the œsophageal varices carried out through the œsophagoscope, or ligature of the coronary veins are both methods that are on their trial (see Vol II, Œsophagus) Thrombosis of the splenic vein may follow the operation and it may spread to the superior mesenteric vessels, causing the classical symptoms of mesenteric thrombosis

Results.—The removal of the spleen for injury may be a very serious matter because of severe hæmorrhage or the severity of associated injuries The mortality is about 20 per cent The after history of survivors shows that for the most part they enjoy good health and are able to withstand the onslaught of the ordinary diseases like influenza, pneumonia and appendicitis But a careful study of 100 cases by Ask-Upmark * led him to the conclusion that there was an increased tendency to digestive disturbances, blood changes and unexplained exhaustion But at the present time most removals of the spleen are undertaken for some type of disease, and the prognosis, both immediate and remote, largely depends on the stage of the malady at which the operation is carried out When splenectomy is recognized to be the best or perhaps the only method of treatment it should be performed as early as possible Immediate mortality is still much too high, due probably to the fact that it is not yet possible to make an exact choice of the most favourable cases Recent figures from the Mayo Clinic (to end of 1930) show 211 cases of splenectomy for all conditions with only 15 deaths a mortality of 7 11 per cent At the present time excellent results are being obtained in *hæmolytic jaundice* and *early splenic anæmia*

In hæmolytic jaundice the results, immediate (4 per cent mortality) and remote, seem to be the best, and in the majority of cases the operation leads to a cure, although the blood fragility persists In splenic anæmia operation undertaken before liver involvement has a mortality of about 10 per cent, and recovered cases enjoy much improved health for a number of years

* *Acta Med Scand* Suppl 1936, lxxviii 276.

CHAPTER XIX

OPERATIONS FOR INTESTINAL OBSTRUCTION

By G. GREY TURNER

INTESTINAL obstruction may be sudden or gradual in onset, or it may present itself as an acute exacerbation of a longer standing partial obstruction In the sudden acute obstructions it is the small intestine that is generally affected Though acute obstruction of the large intestine does occur, as in volvulus, in most cases malignant stricture is the commonest cause and a history of gradually increasing obstruction can usually be obtained The commonest cause of acute intestinal obstruction is strangulated external hernia, which is considered in Vol II In this article only conditions arising from intra-abdominal obstructions will be discussed Putting aside congenital abnormalities, such as intestinal atresia and imperforate anus many conditions may give rise to intestinal obstruction, but they may be roughly classified as (1) abnormalities within the intestinal lumen, (2) abnormalities of the intestine itself, and (3) abnormalities obstructing the intestine from without

In the *first* type the characteristic condition is a gall-stone or much more rarely an enterolith or a mass of undigested food, giving rise to partial or complete obstruction low down in the ileum

In the *second* type obstruction is not uncommonly caused by tuberculous ulceration, by polypi either directly obstructing or giving rise to intussusception, by intussusception, by mesenteric thrombosis, or by volvulus and in the large intestine, by malignant growths and volvulus

In the *third* type the intestine may become attached to or obstructed by tumours, etc , e g , the duodenum by cancer of the pancreas, the small intestine by tuberculous mesenteric glands, the transverse colon in gastric cancer. More commonly, the intestine is strangulated by bands or adhesions resulting from local peritonitis These conditions may follow a previous operation, as for appendicitis, hysterectomy, ovariotomy, or strangulated umbilical epiplocele Bands also form between neighbouring coils, giving rise to a " double barrelled gun " or " concertina type of deformation Fortunately it by no means follows that adherent coils are necessarily obstructed In other cases long bands form, from mesentery to mesentery, from mesentery to gut, from gut to gut, and so on, and these may strangle the coil to which they are attached or a neighbouring coil In this category comes the *appendix*, the tip of which may become adherent, so that it forms a band attached at each end, and *Meckel s diverticulum*, which may not only form a band but may cause axial rotation of its attached

portion of intestine or become inverted into the lumen of the bowel giving rise to intussusception Rare instances are reported of a coil of gut being imprisoned in a hole in the omentum or mesentery and there are many retroperitoneal fossæ into which internal hernia may occur e g the foramen of Winslow the duodenal retrocæcal and sigmoid fossæ The obstruction may be entirely mechanical or it may be combined with strangulation in which case the blood supply is suddenly arrested But the distinction is of more academic interest than practical importance for both groups require the earliest possible operative intervention

Indications for operation —There is no doubt that the high mortality attending acute intestinal obstruction (25 to 30 per cent) is due in great measure to delay in instituting active treatment It cannot be too strongly emphasized that it is much more important to make a diagnosis *and act upon it* than to spend valuable time in efforts to make a differential diagnosis of the cause which may have no bearing on the problems of treatment The matter can be summed up in a few words laparotomy is the only treatment for acute intestinal obstruction and it should be undertaken at the earliest possible moment The cardinal symptoms are pain vomiting and cessation of the passage of flatus and fæces Distension is a comparatively late sign except in low-down obstructions and fæculent vomiting is a later sign still It should be possible to make a diagnosis before either of these signs supervenes and their presence adds enormously to the difficulties and dangers of the operation As Sampson Handley says fæcal vomiting is not so much a sign of intestinal obstruction as a herald of approaching death

But there are many difficulties in diagnosis which have a bearing on treatment especially (*a*) where the obstruction is due to inflammatory disturbances which may subside with time and suitable treatment (*b*) where the obstruction is adynamic or paralytic the result of toxins and profound neuro-muscular exhaustion

The inflammatory type is usually a sequel to peritonitis and is therefore not an infrequent complication of appendicitis It often accompanies the attempt at localization of an intraperitoneal abscess and frequently disappears when such an abscess suddenly discharges through the wound or is opened per rectum These patients often lack the characteristic symptoms of mechanical obstruction for pain is more continuous than colicky there is diffuse tenderness the vomit is not characteristically intestinal and they often void some flatus The surgeon must be on the look out for some localized abscess which might be opened During the period of uncertainty it is wise to apply heat effectively to the whole abdomen and to administer an enema once or twice The stomach should be kept empty by a Wangensteen or Ryle s tube or the coils of small intestine by the Miller Abbot tube while at the same time the water balance and chloride level is being maintained by intravenous injection But it is necessary to add a caution for even the worst cases of mechanical obstruction will be

temporarily relieved by these methods, so that unless there is coincident evidence of a return to normal intestinal function it is illusory to persevere in their use for more than a few hours

The adynamic or paralytic ileus type may have an underlying inflammatory cause but it may also be the result of exposure or handling of the intestines or absorption of toxins from the bowel itself, or of pure nervous exhaustion It is best treated by rest by making up for fluid loss and by providing nourishment in the form of glucose administered intravenously Such forms of stimulation as will improve the neuro muscular mechanism of the intestines are valuable drugs like strychnine and eserine in small doses repeated at regular intervals Diffusible stimulants are also useful Inhalation of pure oxygen by means of the B L B mask, used continuously for six hours is one of the latest methods of combating this condition and appears to be helpful Very often sleep is lacking and if it can be induced by sedative drugs or indeed by whatever means improvements often result

When the fact of mechanical obstruction is established it is of great practical importance to decide whether the causative factor is in the small or the large bowel In the former case an exploratory laparotomy is the proper proceeding whereas in the latter some form of colostomy will probably be indicated

Preparation—In nearly every case, two or three hours may advantageously be devoted to preparation This especially applies to patients who have just been brought into hospital often after an exhausting journey One of the first indications is to see that the patient is made generally comfortable, and well warmed Blankets with hot bottles or electric pads are essential Once an operation has been decided upon, there is no objection to the use of a small dose of morphia (gr $\frac{1}{8}$ to $\frac{1}{4}$) if there is much pain, otherwise sedatives should not be employed In addition to these general measures the indications are (1) to make up for fluid loss (2) to restore the depleted chlorides, (3) to counteract alkalosis (4) to decompress the stomach and upper intestine, and (5) if it has not already been done, to empty the rectum and lower bowel The first three objects may be attained by the administration of 5 per cent glucose in normal saline, either by the rectum, by surface injection, or intravenously, 3 or 4 pints (approx 2 to $3\frac{1}{2}$ litres) may be administered in an average case To empty the stomach and decompress the upper intestine, a Wangensteen or Ryle s tube is used either as a syphon or to withdraw the contents by means of a syringe It is important to start with the rectum empty, and this can best be attained by a glycerine or simple soap and water enema Patients often improve in a wonderful way as the result of these measures, but if the surgeon has previously been satisfied of the necessity for operation he must not be misled by what will certainly prove to be only temporary benefit

Anæsthesia.—This question is most important If regurgitant vomiting is a feature, general anæsthesia should be avoided whenever

possible Local anæsthesia is sufficient for cæcostomy or colostomy or enterostomy which can be carried out very satisfactorily and with scarcely any pain after thorough infiltration of the parietes The abdomen can also be opened and the easily accessible coils of small intestine examined and in this way most cases of obstruction due to easily accessible bands or adhesions or impaction of gall stones can be dealt with Should it be necessary to explore the abdomen thoroughly or to reach inaccessible parts ordinary local anæsthesia is insufficient but it can always be supplemented by giving gas and oxygen alone or with ether Generally speaking patients who are not in a condition for general anæsthesia have too low a blood pressure for the safe use of spinal anæsthesia but should it be otherwise then this method provides the most wonderful relaxation and greatly facilitates operations which necessitate a complete exploration

OBSTRUCTION IN THE SMALL INTESTINE

These cases are of greater urgency than those of large intestine obstructions and after suitable preparation exploratory laparotomy is the correct procedure

Technique —The placing of the incision is a matter of considerable importance If there has been a previous operation likely to bear an ancestral relationship to the obstruction the abdomen may conveniently be re opened just by the side of the old scar It is necessary to bear in mind that distended coils of intestine may be adherent to the peritoneal aspect of the scar and must not be inadvertently opened or otherwise damaged When there has been no previous operation a median sub-umbilical incision generally gives the best access An incision of about 4 ins long may suffice but in case of difficulty the surgeon must never hesitate to enlarge the wound Care must be taken to prevent the intestine from prolapsing through the incision and this is best attained by covering the area with large moist swabs It is often impossible to prevent a certain amount of evisceration and in that case great care must be taken to cover the exposed bowel and to keep the swabs moist by trickling warm saline over them from time to time As soon as the peritoneal cavity is opened some fluid will be found and if it is blood stained strangulation is probably present Not infrequently the site of the obstruction will at once be disclosed but usually some further search is necessary Two fingers inserted into the abdominal cavity may quickly discover a mass of adhesions a coil of tense distended bowel obstructed by a band a loop passing into a hernial orifice or a foreign body impacted in the intestinal lumen Sometimes the source is not so easily found in which case the bowel must be searched up or down until the obstructed area is located Collapsed gut takes less harm from handling than distended gut and whenever possible it should be traced If collapsed gut is not found there is nothing for it but to trace the distended bowel but in that case the gut is not so easy to handle readily

bruises and is likely to be torn If it is so much distended that the peritoneum begins to tear, it should be opened for temporary drainage For this purpose a distended coil is gently withdrawn from the abdomen and a small incision made on the antimesenteric border just large enough to accommodate a 10 or 12 rubber catheter, which is loosely anchored in position by a purse-string suture If the bowel is not paretic it may be expected to empty fairly well, but if it does not do so the catheter may be advanced further and the bowel may also be milked down towards the catheter, when a good deal of the contents will escape The process may be further assisted by giving a dose of pituitary extract The coil, with the catheter *in situ* is allowed to hang over the side of the incision At a later stage the catheter is removed and the incision closed with the purse-string and if necessary, one or two Lembert sutures Moynihan's tube has been recommended for the same purpose but it inflicts too much trauma on the intestine The tension having been relieved in this way, the search may be continued with less risk to the intestine When the site of obstruction has been located the cause must next be ascertained

Obstruction by adhesions.—These cases vary from the simplest V-shaped angulation at a single point to the most complicated mass obstructions When the seat of the obstruction is found a decision has to be arrived at on the following points

(1) Is it a case of angulation, or of strangulation, where gangrene threatens ?

(2) Can it be dealt with by simple separation of adhesions or division of a band ?

(3) If more extensive methods are necessary, must the affected loop be short circuited or resected ?

(4) Should drainage of the intestine, whether temporary or protracted, be instituted ?

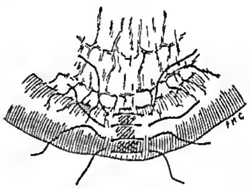

Fig 449 —Area of small intestine, damaged by pressure of a band or adhesion, being tucked in by Lembert sutures

Strangulations are usually obvious because of the deep blue or sometimes almost jet-black colour of the intestine This is nearly always due to a band, herniation through an aperture, or mesenteric thrombosis Bands sometimes give way on the slightest handling or they may be very tough and require division by scissors Any long band should be excised and not merely divided, lest it should cause further obstruction The condition of the gut must be carefully inspected, the changes which may be found and the treatment required are exactly the same as in strangulated hernia (Fig 449) (See Vol II) If the obstruction is caused by adhesions, these should be separated under the guidance of the eye as far as possible, for the gut is so easily torn during blind

separation When the involved area is at the bottom of the pelvis the Trendelenburg posture may be a great assistance The intestine at the site must be carefully inspected after the separation Sometimes there are many points of adhesion and the separation must be continued until it is certain that the obstruction is completely relieved Where the adhesion is to an old tuberculous gland the intestine is particularly likely to give way Any hole into the bowel must be carefully repaired by suture though, if there is a tendency to a free escape of bowel contents, the bowel should be allowed to empty itself as completely as possible before closure More frequently, only the peritoneal coat is torn but it may be torn in numerous places If shreds of peritoneum can be easily replaced and fixed by a point of suture so much the better, but if this is not possible and the condition demands that the operation should be terminated without delay these areas may be allowed to look after themselves provided always that the lumen has not been opened If there are many raw areas with free bleeding, saline should be poured into the cavity so that the peritoneal surfaces will be kept apart for some hours Usually the abdomen can be closed without drainage, but if any considerable abscess has been opened it is wise to bring a tube from the pelvis and out at the lower end of the parietal incision Sometimes several coils of intestine are so closely adherent that it is well nigh impossible to separate them In these circumstances it is best to short circuit the area by lateral anastomosis but no greater area of bowel should be excluded than is essential Resection is seldom required except where there has been strangulation Only very rarely is external drainage of the small intestine required and enterostomy with its risk of dangerous sequelæ should be avoided whenever possible As a rule, a rapid closure of the parietal incision is required, and for this purpose a continuous suture of the peritoneum, followed by through and through sutures of silkworm gut for the other layers, is effective and safe

Treatment of mass obstructions.—In these cases many coils may be bound together by adhesions in what seems and often is, an inextricable tangle This type of obstruction is perhaps most often met with as the result of caseating tuberculous mesenteric glands, or of pelvic peritonitis following appendicitis Attempts to separate the adhesions will almost always be unsuccessful and if persisted in will probably make a wide resection inevitable, or at best leave raw surfaces which will form fresh adhesions There is little risk of gangrene, as the coils are sharply kinked rather than strangulated, so that there is no additional risk in leaving the mass in the abdomen The correct procedure therefore is to *short circuit the obstruction*, making a lateral anastomosis between two coils of gut, one on either side of the obstruction It is necessary to exclude as small an amount of intestine as possible therefore it is important to make the union between a coil just above to one just below the obstruction It is sometimes impossible to expose unobstructed small gut below a mass of adhesions in the lower ileum In such circumstances the union may be made

between the small bowel above the obstruction and the cæcum There may be a temptation to make an end to side anastomosis but lateral union has the advantage that after the obstruction settles down some of the intestinal contents may find their way through the normal channel and that if the obstruction is absolutely complete the piece of bowel between the anastomosis and the obstruction can regurgitate its contents to the anastomosis rather than become dangerously distended with infected mucus (see Fig 473 p 929) In mass obstruction where the involved area can be freed from the parietal peritoneum and brought outside the abdomen resection with immediate anastomosis may be the best course

Treatment of strangulation by bands—In these cases a coil of gut is constricted by a band and suffers just as the coil of gut does in a strangulated hernia i e there is not only obstruction of the lumen but interference with the blood supply and if unrelieved the condition goes on to gangrene The site of obstruction must be exposed and the constricting band divided The constricted loop is then examined as in strangulated hernia to estimate its viability The lines of constriction at the two ends of the loop are examined and also the loop itself If the constriction has not bitten into the gut if the loop has retained its glistening appearance and if its shows signs of revival after being wrapped up for a few minutes in a hot swab it may be expected to recover even if considerably congested If however the lines of constriction are deeply cut or ulcerated or if the loop has lost its polish is limp or toughly œdematous and more especially if it shows patches of what is probably commencing gangrene it cannot be expected to recover and *enterectomy must be carried out* End to end anastomosis is the best way of restoring continuity of the bowel (see p 911) There is no alternative to this course for though the offending loop may be withdrawn from the abdomen anchored there and opened thus creating a fæcal fistula the case usually ends fatally as the result either of continued toxæmia or the loss of intestinal contents The latter cause is especially operative when the opening has to be made higher than about three feet above the ileo-cæcal valve Subsequent attempts to close the fistula have been attended by a high mortality

Post-operative prevention of adhesions—A great deal of work both clinical and experimental has been done on this problem It is first necessary to recognize that the principal causative factor is infection rather than trauma None the less anything that injures the delicate endothelium of the peritoneum is harmful and all intraperitoneal manipulations should be conducted with great gentleness Gauze held in sponge handles should never be screwed round in an effort to clean up some area There is some doubt whether blood in the peritoneum leads to the formation of adhesions or whether it may have just the opposite effect While it is certainly not necessary to irrigate the peritoneum in an attempt to remove all blood it is best

to remove gross masses of clot These are best baled out with the hand Rough gauze swabbing should never be used Adhesions which have to be broken down after some intraperitoneal inflammation are not so likely to re form as is often supposed With these reservations it is well to recognize that as far as possible all areas denuded of peritoneum and all raw or rough areas should be covered by peritoneum or by some organ as for instance when the uterus or a loose pelvic colon is turned back over a raw area in the bottom of the pelvis When neither of these plans can be employed the omentum may be used as a protective either as it is or in the form of an isolated graft Another plan is to prevent structures that might become adherent such as intestine from coming into contact until at least a certain amount of repair at the traumatized region has taken place Incidentally it is surprising in how few hours such areas are covered by lymph which soon organizes and in turn becomes covered by endothelium To keep viscera apart until this reparative process gets started normal saline left in the peritoneal cavity probably serves the purpose as well or better than anything else Various substances like oil and protective materials like cargile membrane thin rubber or cellophane have been tried but there is little or no evidence to show that they attain their object

RETROPERITONEAL HERNIA

During the development of the intra abdominal organs changes of position occur especially of the stomach and duodenum of the mesentery and of the cæcum and fusions take place between peritoneal layers on the posterior and lateral walls of the peritoneal cavity As a result at certain points folds and fossæ occur which may be large enough or become large enough to contain intestine and it happens from time to time that a coil of gut entering one of these fossæ becomes constricted and strangulated Many names have been given to these fossæ of which a great many have been described The subject was well reviewed by Moynihan and Dobson * From the surgical point of view those of most importance are the paraduodenal fossa of Landzert into which the left duodenal hernia passes and the mesenteric parietal fossa of Waldeyer which is the site of a right duodenal hernia A few cases of hernia occur into fossæ around the cæcum and appendix into the intersigmoid fossa and even into the foramen of Winslow through which a large amount of the small bowel may find its way into the lesser sac

In this type of hernia the sac may be large enough to contain the whole of the small intestine so that there are symptoms of very high obstruction without abdominal distension From the operative point of view importance lies in the fact that the necks of the fossæ are generally closely surrounded by blood vessel Thus the neck of the paraduodenal fossa has the inferior mesenteric vein in the upper

* Retroperitoneal Hernia 2nd Edn 1906

horn, and the left colic artery in its lower The neck of the fossa of Waldeyer has the superior mesenteric artery and vein in its anterior margin It is therefore a critical proceeding to enlarge the ring to release the hernia, and closing the ring to prevent a recurrence is equally dangerous Fortunately, there is rarely any difficulty in withdrawing the intestine from the sac, but when there is the neck should not be nicked but should be stretched with the fingers Should the intestine be reluctant to leave, the surgeon must make pressure on the sac while at the same time gentle traction is made on the entering bowel, not on the mass but on one or other of the separate pieces To effect reduction it may be necessary to open the sac and to puncture and empty some of the coils of contained intestine to diminish their bulk

The diagnosis is seldom made before operation the abdomen being opened for obstruction The treatment of the constricted intestine is on the same lines as in strangulated hernia elsewhere (Vol II)

OBSTRUCTION BEYOND THE CÆCUM

Blind cæcostomy.—A good deal of discussion has ranged around the question whether the surgeon should be content to make a blind cæcostomy or whether this should be preceded by an exploration of the abdomen The answer depends on the situation of the obstruction, the condition of the patient, and the degree of abdominal distension If the surgeon is able to determine definitely before operating that the obstruction is beyond the cæcum then there can be no objection to making a blind cæcostomy The only real risk is that the surgeon might open the cæcum when he ought really to be dealing with an obstruction in the small bowel No one will deny the advantages of a general exploration in cases in which a cæcostomy is necessary as a part of the management of obstruction due to a malignant growth of the large bowel It is a great advantage, for instance, to ascertain whether or not the condition causing the obstruction can be dealt with there and then, or if there must be a second operation, and whether at such an operation radical interference will be possible or only some further palliative measure, but no such exploration can be safely carried out with a very ill patient or a much distended abdomen In some patients the diagnosis is made sufficiently early for the exploration to be made in safety, even though it can only end with a cæcostomy as the first stage of a subsequent operation for the removal of a growth In other cases the abdomen is much too distended and the patient is far too ill to permit a general exploration In these circumstances blind cæcostomy should be performed Between these two extremes there are cases in which the experience and judgment of the surgeon must help him to decide what course to pursue If blind cæcostomy is decided upon, the surgeon must be satisfied, after having exposed the cæcum, that the obstruction is in the large bowel If there is any doubt, the parietal incision must be enlarged so that the small intestine may be explored If the cæcum is empty and collapsed,

the obstruction is in the small intestine if the cæcum is tense and distended the obstruction is below that part of the bowel

Exploration for large bowel obstruction—There are few causes of large intestine obstruction other than volvulus or malignant stricture and volvulus whether of the cæcum or of the sigmoid would be obvious immediately the abdomen was opened The probability is that a malignant stricture will be found and the colon must be methodically examined from below upwards because growths causing obstruction are much more common in the left colon than in the right When the seat of obstruction is found it will be recognized by the change from collapsed to distended intestine but the growth will often be small and of the constricting type and may be overlooked if the surgeon is expecting to find a considerable tumour Having been located the growth is examined to make sure that a loop of small intestine is not adherent to it and obstructed as happens occasionally in cancer of the descending colon The liver must be examined for secondary deposits and if they are absent the growth is more carefully examined to determine the prospects of a subsequent operation for its removal The wound is then closed and a separate incision made in the right iliac fossa and the distended cæcum brought up to the wound and opened When the growth is not considered removable or if this point is in doubt two other courses are available When situated above the pelvic brim a lateral anastomosis may be made between the cæcum or some other proximal part of the colon and the bowel below the growth If situated at the pelvic brim or just beyond a colostomy may provide the best form of relief or will suffice to drain the bowel and to provide for physiological rest in the hope that after a period of a few weeks the conditions around the growth may have so much improved as to bring it within the range of palliative removal When a second stage radical removal is contemplated some surgeons prefer to make a dysfunctioning type of colostomy (Devine) In these circumstances I consider that cæcostomy provides a sufficient protection and it has the very great advantage that having served its purpose it can be easily and safely closed at a single sitting

Technique of cæcostomy—This is best performed under general or spinal anæsthesia for though local infiltration anæsthesia enables the intervention to be carried out without pain there is a risk of necrosis of the wound edges probably encouraged by the fæcal contamination which is bound to occur The incision should be an oblique one across a line from the anterior superior iliac spine to the umbilicus and at the junction of its outer with its middle third (Fig 450) In spare subjects an incision of two inches or even less will suffice but it may have to be 4 to 6 inches long in the obese The peritoneum is opened and the cæcum identified in handling the latter the surgeon must remember that if it is distended it may be readily injured and that sutures will not be easy to apply without tearing If there is any difficulty in bringing the cæcum into the wound because of distension

it will be safer to puncture it *in situ* with a trocar and cannula With the escape of gas and perhaps liquid fæces the cæcum becomes flaccid and in this state it must be held with forceps and withdrawn from the incision with the cannula still retained The latter is not removed until the bowel has been safely fixed to the parietes The cæcum having been fitted into the wound is attached to the edges of the peritoneum by a few points of catgut suture Another method is to draw the ends of the abdominal incision together with a silkworm stitch which also takes a bite of the wall of the bowel but without entering its lumen In either of these ways an area of the cæcum like half a tangerine orange is fixed outside the abdomen This may be opened immediately if the obstruction is well marked or opening may be deferred for 24

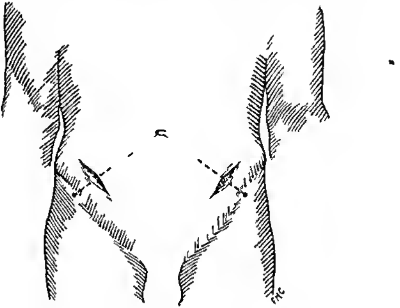

Fig 450 —Incisions for cæcostomy and colostomy

to 48 hours so that the peritoneal cavity may be securely shut off by the formation of plastic exudate

The cæcum is opened by an incision about an inch long in the summit of the part exposed This suffices for the insertion of a moderate sized Paul s tube which is securely tied into the bowel with strong silk If the area of the cæcum is not sufficient for tying in a tube the edges of the incision into the bowel may be fixed by stitches to the edge of the wound or the skin beyond at about four equidistant points This method is satisfactory and there is no special risk of infection of the parietes It has the disadvantage that there is no means of conducting liquid fæces away from the area during healing A Paul s tube loosens at the end of a week or ten days and should then be removed By this time whichever method has been employed the cæcum will be well exposed beyond the level of the skin and the greater part of the intestinal contents will find a ready exit The

bowel beyond can be easily irrigated from the cæcal opening and it may also be possible to wash it out through a rectal tube the fluid returning through the cæcostomy

Difficulty in bringing the cæcum outside the wound—This may be due to excessive distension to the absence of a meso-cæcum or to pathological adhesions When the cæcum cannot be brought to the surface without undue tension some other part of the large bowel should be opened—most conveniently the transverse colon When the obstruction is in the ascending colon ileostomy may be substituted for cæcostomy

Safety valve cæcostomy—In this method a large sized rubber catheter (No 14 or 16) is fixed into an opening in the cæcum and slightly buried in the bowel wall by two or three surrounding purse string sutures (Fig 500 p 1007) This may be done without with drawing the cæcum from the abdomen or it may be returned and anchored to the parietal peritoneum by one or two sutures Though this method has its uses in the treatment of peritonitis it cannot be recommended for the relief of obstruction or as a preliminary to the removal of bowel growths

It is to be remembered that cæcostomy in any form is only a temporary expedient and is not intended for permanent drainage Indeed drainage of the cæcum and right colon is attended with so much discomfort owing to the fluid discharge that a permanent opening on this side should be avoided whenever possible

Colostomy—Where the character of the obstruction makes it probable that the drainage must be permanent colostomy is indicated The intestinal contents become less and less fluid from above downwards the fæces becoming formed at or about the middle of the transverse colon A fluid fæcal discharge over which the patient has no control is very trying so that colostomy is rarely done except in the transverse or the left colon obstructions of the right colon being overcome by ileo transverse colostomy if that is possible Colostomy is always made on the front of the body by the transperitoneal route The lumbar method has nothing to recommend it and is now obsolete In addition to the greater ease of the anterior operation it has the enormous advantage that the opening is in a position where it can be seen and attended to by the patient

Transverse colostomy is said to have certain advantages over inguinal colostomy in that the artificial anus is more readily cleaned and an apparatus is more easily fitted but nevertheless the inguinal route is that usually employed

Inguinal colostomy—This operation is merely for the purpose of draining the colon and no exploration of value can be conducted through the small incision which is all that is necessary for making the colostomy It is not a good plan to enlarge this incision for exploration as hernia is almost certain to follow and a colostomy opening perched on the top of a ventral hernia is very unsatisfactory

If exploration is required a separate sub umbilical incision should be made As grave issues often depend on this exploration it may be necessary to put the patient in the Trendelenberg position and to inspect as well as palpate the growth When this midline incision is employed the separate small incision required for the colostomy may be more easily made from the outside when the fingers of the hand inside the abdomen are used to make its wall prominent at the site for the incision This method is sometimes spoken of as a stab wound but anything so suggestive of violence is unworthy of a place in modern surgery The best place for colostomy is an oblique incision in the left iliac fossa not too near the iliac spine (Fig 450) It should be made across the junction of the outer with the middle third of a line drawn from the anterior superior spine to the umbilicus Some operators prefer an incision through the rectus muscle or at its outer border Whatever its situation the incision should be as small as will suffice but its length will depend on the build of the patient for in very stout subjects it must be longer than in those that are spare The object of making a short incision is to prevent prolapse of the small intestine by the side of the colostomy to diminish the risk of prolapse of the colostomy itself and to prevent subsequent hernia at the site Some surgeons use a muscle-separating incision under the mistaken idea that it gives the patient a measure of voluntary control such an approach hampers the surgeon and may constrict the bowel so much as to lead to gangrene of some part of the loop The peritoneum having been opened the large bowel must be identified and withdrawn from the abdomen On occasion it may be difficult to find the bowel and the incision may have to be enlarged for the purpose In rare cases it has been necessary to inject air or fluid per rectum to distend the bowel for identification The common mistake is to look for the bowel too far towards the centre of the abdomen generally speaking and especially when the mesosigmoid is short it will be found below and external to the incision and nearer the iliac spine The large bowel is usually recognized easily by its longitudinal bands and appendices epiploicæ at least in this situation but it may be difficult to draw it outside the abdomen and this may depend on the shortness of the mesosigmoid or on adhesions which are very common on the outer side Adhesions can usually be exposed and divided thus mobilizing the bowel In the rare cases in which the mesosigmoid is so short that the bowel cannot be withdrawn it is better to make an independent transverse colostomy The bowel having been identified it is necessary to select a portion which will leave four or five inches of sigmoid above the opening as a fæcal container

With the small opening which is commonly employed to-day there is very little risk of prolapse and in any event as often as not the prolapse is of the lower segment of the bowel Having selected the bowel to be utilized it must be withdrawn until the antimesenteric border is level with the abdominal wall To prevent it from retracting into the abdomen and to ensure the formation of a good spur an old

pair of artery forceps is passed through the mesentery from the umbilical side this is better in every way than the glass rod which is sometimes recommended as forceps are always to hand and glass objects may break (Fig 451 a) Some surgeons attain the same object by putting a stout silkworm mattress stitch through the incision and the mesentery of the loop while others draw the abdominal wall together beneath the loop after sufficiently dividing the mesentery and controlling the vessels It is next necessary to fix the bowel at either end of the incision to prevent more than has been selected from escaping from the abdomen A silkworm stitch is passed at either end including the skin and the aponeurosis of the external oblique it then secures a good bite of the bowel through one of the longitudinal bands but without entering

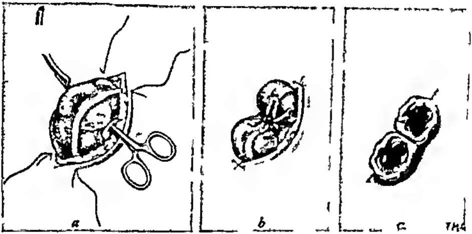

Fig 451 —Technique of colostomy

a Artery forceps as colotomy rod with rubber tube b Rubber tube has been tied round loop over the opening made by cautery to let out flatus. c The completed colostomy

the lumen and traverses the same tissues on the opposite side When the epiploic appendices are large or numerous and especially if they are unusually pendulous it is wise to ligature them near the bowel and to cut off the excess Though this is not essential it is helpful in convalescence for though the appendices always gradually shrivel up the process may take a long time As a last step in the operation a piece of strong rubber tubing about $\frac{3}{8}$ in in diameter and 10 in long is caught in the forceps which have been passed under the bowel for use as described later The bowel is then covered with a piece of green protective or old rubber glove and dressings are applied During the first 48 hours if flatulence is very troublesome it may safely be relieved by a dose or two of opium but at the end of that time when the peritoneal cavity may be expected to be safely shut off a puncture is made in the summit of the colostomy with the cautery This allows gas to escape and usually makes the patient quite comfortable This puncture may be made at the time of the operation if the bowel is much

distended, and if the obstruction is really acute a freer opening must be made and a Paul's tube tied in. In an ordinary case, at the end of a week, the artery forceps is withdrawn through the mesentery, carrying with it the rubber tube (Fig 451, b). The latter is tied as tightly as possible around the bowel just below or over the puncture previously made. In about 48 hours the elastic pressure cuts through the bowel painlessly and without hæmorrhage, and provides a very convenient way of opening the colostomy (Fig 451, c). This method was devised by Professor Rutherford Morison and has proved entirely satisfactory.

Sometimes the elastic stops short of complete division of the gut, but when this is so, any tissue left in the grasp of the ligature is crushed and avascular and can be divided with the cautery or even with the scissors without much risk of hæmorrhage. In order to prevent the fæcal contents from getting into the lower segment it is necessary to divide the bowel completely in this way. Should the colostomy be intended to be only temporary, complete division of the bowel is not usually considered necessary and its lumen may be cut half across on the convexity, or a longitudinal incision may be employed. In this event the elastic ligature is not indicated. As a matter of fact, even for temporary colostomy, it is better to divide the bowel completely, or fæcal matter will be sure to reach the lower end. In actual practice it is as easy to repair a complete colostomy as the sort of fæcal fistula into which a partially divided bowel degenerates.

Paul's method of colostomy.—In this operation the summit of the selected loop is brought up to the abdominal wall but is not withdrawn from the abdomen. The base is stitched all round to the peritoneum and transversalis by a continuous suture of catgut. A circular or elliptical portion of the whole of the bowel wall not more than an inch in diameter is excised from the summit of the loop and the margins of the opening so made are sutured to the skin of the parietal incision. The opening is made piecemeal and is stitched to the skin bit by bit, to diminish the risk of contamination. The orifice should not be larger than will comfortably admit a finger. Mr Paul always held that this type of colostomy gave the best result though it is admitted that contraction is more likely to follow than in the type in which the whole bowel is brought out on to the abdominal wall. To prevent contraction, the patient is directed to wear an aluminium colostomy plug, which is retained in position by a pad of wool and a belt.

Transverse colostomy.—The incision of about two inches long is made either in the middle line or through the left rectus muscle just above the level of the umbilicus. The transverse colon varies very much in position but the omentum provides a guide. A loop of bowel is brought out of the incision and the omentum attached to it is removed or sufficiently freely separated to allow of its being returned to the abdomen. The gut is fixed as described for inguinal colostomy. Occasionally the mesocolon is so short that the bowel cannot be brought out of the wound; the surgeon must then either be content with a fæcal fistula into the colon or must make an independent cæcostomy.

Modifications of colostomy—These are generally devised in the hope of affording some measure of control over the artificial anus but it must be admitted that even partial control by sphincteric action is rarely if ever obtained By any method the patient may and usually does acquire a habit so that he knows when the bowel is likely to act and can be prepared To acquire this habit takes time often many months and sometimes as long as one or two years A permanent colostomy for non malignant conditions or after successful excision of the rectum for cancer need be so little of an encumbrance that patients can engage in ordinary occupations with comfort and confidence It was hoped that if the oblique muscle fibres of the internal oblique were separated as in McBurney s appendix operation or if the rectus muscle were separated and the loop of sigmoid flexure brought out through the muscle a sphincteric action would result Ryall suggested that not only should the rectus muscle be split but that a strip of muscle still left attached at each end should be drawn over the loop from each side so that the contraction of the muscle would act as a sphincter In the Lilienthal method the bowel is divided the upper end rotated axially 180-360° according to the thickness of the wall and the twisted gut retained in that position by suture A tube is tied into the upper end for a distance of 6 in and kept there for a week Lilienthal maintains that the narrowed lumen resulting from the rotation constitutes a partial sphincter *

Accidents that may attend colostomy—Sometimes the small intestine or omentum escapes by the side of the large bowel and prolapses through the wound to a considerable extent The escaped bowel may become strangulated This accident usually occurs in the few hours immediately after the operation but it may take place the next day or—in feeble subjects—as long as a week afterwards Such an accident can be guarded against by making the parietal incision no larger than is absolutely necessary for the loop of large bowel and also by fixing the latter to the edges of the wound It must be treated by cleansing the prolapsed bowel returning it to the abdomen and putting a few additional sutures into the incision The small bowel may also be strangulated around the colostomy i e between the attached sigmoid and the parietes within the abdomen This accident is more likely when the large bowel is brought through the rectus muscle *Gabriel*† reported five cases all of which proved fatal He suggests that inguinal colostomy should be made near the anterior superior spine and that the sulcus on its outer side should be closed by a purse-string suture as suggested by Rankin of the Mayo Clinic I have never known this accident occur when the incision is made not more than an inch and a half internal to the anterior superior spine

The colostomy opening may retract into the abdomen—This may happen quite suddenly or may develop gradually It can only occur in cases in which there is no support through the mesentery or after the latter

* *Ann Surg* 1910 li 384

† *Proc Roy Soc Med* Jun 1929 xxii 1433

has been removed Of course it is more likely to take place when the mesosigmoid has been very short and the bowel is retained in the wound at considerable tension Cases are recorded in which it has happened after the bowel has been opened, and sometimes the bowel contents have been discharged into the peritoneal cavity Even in the latter circumstances, with prompt intervention, it has been possible to cleanse the abdomen and to remake the colostomy, with recovery, none the less it is a most serious accident and great pains should be taken to guard against it

Gangrene of the loop of bowel has usually followed a very small opening in the abdominal wall such as may result from a tight muscle splitting incision As a rule it remains strictly limited and can be dealt with by cutting away the necrosed part of bowel Occasionally the infective process has spread and caused fatal peritonitis

Phlebitis of the mesenteric vessels has led to death from portal pyæmia It can neither be foreseen nor prevented, but it is well to bear in mind the general rule that in the presence of potential infection large venous trunks should not be perforated by sutures or other foreign bodies

Abscesses in the abdominal wall round about the colostomy opening occasionally occur They do not show much tendency to spread, though cellulitis, and even gas gangrene are not unknown

Extensive ulceration of the skin around the colostomy opening is common only in cases of dysenteric infection, but it may occur in tuberculosis In cases in which it appears soon after the formation of the colostomy and progresses rapidly, the possibility of dysentery should be borne in mind, for it then yields rapidly to treatment by emetine Sometimes it is merely a consequence of inanition, in which case it may be expected to recover as the patient's general condition improves

Sequelæ of colostomy —Stricture of the orifice is the only common condition met with in these days This is to be expected if it is not possible to bring the loop of bowel completely to the surface, or in deliberate operations of the Paul type But it may happen even when a portion of bowel is brought completely out of the wound, for sometimes a sclerosing process goes on around the opening until the latter may be no larger than will admit a quill The explanation of this state of affairs is not obvious Strictures of the first type can usually be prevented by dilating the opening with the finger and directing the patient to wear a special dilator for some weeks after the operation When serious contraction occurs as a late sequel it is usually necessary to remake the colostomy

Prolapse of the colostomy used to be frequent, but is not often seen nowadays Probably it was encouraged by too large a parietal opening As often as not, it is the lower loop of bowel which prolapses and this fact shows that it is not essential to pull down the upper bowel as far as possible, and if this is done it robs the patient of the advantage of a fæcal container The only satisfactory treatment is excision of the prolapsed bowel

After-care of colostomy patients.—As a rule, when colostomy has been carried out as part of an operation for the radical treatment of cancer of the rectum, the patient acquires a very satisfactory "habit" which makes the care of the colostomy comparatively straightforward. When, on the other hand, the colostomy is merely a palliative operation, the patients rarely acquire this "habit" and they are often further distressed by continued discharge from the growth per rectum or by regurgitation through the colostomy. There is no definite plan which will ensure the "habit.". In time, patients discover for themselves the type of diet and the general régime which leads to its development. Usually the bowel may be expected to evacuate at such a time as the bowels were accustomed to move before the operation became necessary. It is convenient to endeavour to form a habit by which the colostomy acts just after breakfast and perhaps once again in the evening, but not during the interval. Some patients have slight discharge after each meal but quite often this is only mucus. There are many colostomy belts on the market and some of them appear to be quite satisfactory, but most tend to draw the exposed bowel into the cup-like apparatus and may keep it œdematous or unduly vascular, and sometimes they seem to encourage prolapse. A great many working class patients prefer to rely on a simple home-made apparatus, which is usually some type of many-tailed bandage or a flannel belt tied with tapes. The exposed bowel is protected by a vaselined cloth, and a ring of cotton-wool, covered by a cap of the same material, forms a sort of receptacle which they appear to find efficient.

An ordinary good-fitting abdominal belt with a shallow cup-shaped receptacle which can be laid over the colostomy makes a good outfit. The necessary cotton-wool can be adjusted around the cup and all kept in place by the belt. The parts round about the colostomy should be kept clean with ordinary soap and water; antiseptics are not necessary, though an occasional application of a spirit lotion may harden and preserve the skin. After cleansing and drying the skin, it is a good plan to dust on some toilet powder. Disorders of the bowel attended by diarrhœa are best dealt with by confining the patient to bed until the looseness of the bowels is overcome by diet and the necessary medicinal treatment. Constipation must be met by regulation of diet and the well-known remedies, but an enema of hot water into the colostomy opening may be the best help. Some few patients find it best to empty the bowel each morning by such an enema.

Operations for closure of colostomy.—This is not usually an easy operation, and always requires a considerable degree of nicety. Although the skin round about is sodden and fæcal-soiled, the parts will have acquired a local immunity by the time the operation is necessary and there is really very little risk of infection and as a rule the wound heals quite well. Any attempt at preliminary cleansing is best carried out with soap and water followed by the use of some spirituous antiseptic solution. The parts are so sensitive that general or spinal anæsthesia is essential. It may be possible to close the bowel

without opening the peritoneum, but there is not the slightest need to make that a criterion, and it is usually much easier if the peritoneum is opened Whatever method is employed, an incision encircles the colostomy opening very close to the bowel and is deepened until it reaches the parietal peritoneum Often the bowel is so closely adherent to the parietes that it runs the risk of being opened or torn during the separation, and therefore this step must be carried out carefully and under the guidance of the eye any small tears in the bowel must be carefully repaired When the peritoneum is reached it may be possible to loosen it from the muscles without actually opening the abdominal cavity, but generally speaking this is impossible and it is easier to open up and divide the peritoneum all round the bowel so that the surgeon can withdraw the latter from the abdomen The edges of the mucous membrane must next be defined, and sometimes this requires knife or scissors as they may have become everted Having been defined, the edges must be drawn together—the upper to the lower—by a continuous suture of chromicized catgut which is conveniently passed from the mucous membrane In this way further eversion is avoided and less of the intestine is required for the union, so that the lumen at the point is not too much narrowed This continuous suture must then be protected and further inverted by stitches passed Lembert-fashion and finally the whole union is reinforced by tacking some of the appendices epiploicæ or adjoining loose tissue over the suture line The bowel may then be allowed to retract into the abdomen or gently pushed back if the operation has been extraperitoneal The defect in the abdominal wall should be carefully repaired in layers by interrupted sutures of stout catgut with the addition of two or three through-and-through silkworm sutures If the surgeon has any doubt of the efficiency of the bowel suture he should bring a small tissue drain from the neighbourhood of the repaired bowel to the surface

About 48 hours after the closure of a colostomy the patient may develop some obstructive symptoms, such as colic with distension, vomiting and inability to pass flatus These are due to swelling of the bowel at the site of the closure and usually subside in a few hours They are to be treated by withholding food and giving a dose of opium, and not by purgatives or enemata If they do not spontaneously subside it usually means that the colostomy will re-open All being well about the fourth day the patient may commence to take liquid paraffin and as a result the bowels will commence to act, though the process may need to be assisted by a glycerin enema When flatus is voided at an early stage the operation is sure to be successful If things are not going well there will be inflammatory mischief around the wound which will probably break down, the colostomy being spontaneously re established Of course, the incision may have to be deliberately re opened Sometimes a small fæcal fistula forms but heals of its own accord

Appendicostomy.—This operation has a limited usefulness as a method of relieving the tension in obstruction of the large intestine

The operation was brought to the notice of the profession by Keetley * though Weir had made the original suggestion† as a method of treating colitis and constipation and it has since been used for drainage in large intestine obstruction and for irrigation in dysentery It has a great advantage over cæcostomy in that there is no risk of soiling the peritoneum and bowel leakage is sometimes prevented presumably by the valve of Gerlach

The abdomen should be opened by McBurney s incision (Figs 492 493 pp 979 981) and the appendix identified and shown to be suitable for the purpose The cæcum at the base of the appendix is attached to the edges of the peritoneal incision by a few interrupted sutures the greatest care being taken not to constrict the artery in the meso appendix The appendix is brought out and the remainder of the peritoneal incision closed The wound is closed by a few interrupted silkworm gut sutures above and below the appendix taking up skin and aponeurosis of the external oblique A suture attaches the appendix to the skin or a safety pin may be passed through the meso appendix at the skin level The tip of the appendix is amputated and a rubber catheter passed through *the appendix into the lumen* of the cæcum When the time arrives to close the fistula it is only necessary to remove the remains of the appendix

INTUSSUSCEPTION

By intussusception is meant the slipping of one section of the bowel into an adjoining generally distal section It is most commonly due to disordered peristaltic action the exciting cause for which has been much discussed but is still in doubt In other cases usually in adults a tumour of the bowel e g a polypus acting as a foreign body excites peristalsis with the result that the tumour is passed along the bowel carrying with it and invaginating its attached segment into the bowel immediately below A malignant growth of the ileo-cæcal valve may be intussuscepted to a point beyond the splenic flexure Sometimes Meckel s diverticulum is inverted into the bowel and causes intus susception but these cases are rare In a series of 40 cases in addition to the malignant case mentioned there were but 2 cases due to polypus one of which was in the colon and one an inverted Meckel s diverticulum

The usual type of intussusception due to disordered peristaltic action occurs at or near the ileo-cæcal junction and is peculiarly a disease of early life the vast majority occurring in children under five years In Fitzwilliam s analysis of 1 000 cases‡ 72 per cent occurred in patients under one year There were very few before the third month a steady rise to the sixth a rapid fall to the eighth and a *further* steady fall to the twelfth Males are more often affected than females (Fitzwilliam males 68 per cent females 32 per cent or in cases under

* *Proc Roy Soc Med* 1908, ii Surg Sect p 67

† *Med Rec* August 9 1902, lxii, 201

‡ *Lancet* February 29 and March 7 1908 i 629 and 709

12 months, males 3 to 1) In the majority of cases the patients are well developed, healthy, breast-fed babies

Indications for operation.—It must be remembered that in the early stages the obstruction is not always complete, so that there is not a typical picture of intestinal obstruction The babies cry and are evidently in pain, vomiting is usual but not insistent and there is very rarely abdominal distension Most cases however begin abruptly with an attack of severe pain and collapse from which they soon recover The classical sign the passing per anum of blood and mucus, is sufficiently constant to be looked upon as pathognomonic but it is not always present in purely enteric intussusception A tumour can be felt in the majority of cases, and in practice the diagnosis is easy and a high average of correct diagnoses is reached Early operative treatment has yielded by far the best results and no time should be lost in trying to reduce the intussusception by inflation, gravitation enemata, or other means In neglected cases, and where the intussusception has reached the rectum it may be justifiable to attempt partial reduction by rectal injection but only in order to reduce the bulk of the mass before operating Unfortunately these are the very cases in which this method is not likely to prove helpful

Technique.—Babies stand exposure and handling of the abdominal contents badly, so that for successful intervention the operation should be completed quickly The anæsthetic is therefore a very important factor, as much time may be lost in closing the abdomen if relaxation is incomplete General anæsthesia is entirely satisfactory, though spinal has been used with success and has the virtue of producing very complete relaxation Every effort should be made to minimize shock and the child s arms and legs should be completely wrapped in cotton wool The abdomen is opened in the median or paramedian line by a vertical incision extending for three inches below the level of the umbilicus There is nothing gained and probably a good deal lost, by making too small an incision for speed is essential, and the operator must not be hampered by want of space in finding and reducing the intussusception But a general escape of the small intestine through the wound should be avoided if possible, and this is much easier with an incision of only moderate size After opening the peritoneal cavity the contents are protected and restrained by a large flat swab laid over the wound and two fingers are introduced and the intussusception felt for and located If the apex has not passed the splenic flexure the whole tumour can generally be lifted or coaxed out of the abdomen, and this should be done whenever possible, as it facilitates reduction

When the apex of the intussusception has reached the descending colon it must be pushed up by the first and second fingers of each hand, the left steadying the intussuscipiens, the right pushing up the apex This may be difficult if the apex has actually reached the pelvic colon or rectum, but short of this it is easy enough In the few cases where the apex has reached the anal canal it may be pushed up by an assistant

with the fingers in the rectum until the pelvic colon below the apex can be grasped between the first and second fingers As soon as possible the tumour should be lifted out of the abdomen and received into a hot moist towel

Reduction is rapidly undertaken the intussuscipiens being held in the palm of the left hand while the fingers knead the intussusception backwards the right hand steadying and replacing the ensheathing layer as it is delivered of the intussusceptum (Fig 452) Reduction is generally easy and rapid until the last inch or so is reached when it becomes more difficult owing to the tension on the ensheathing layer and œdema of the remaining portion (apex) of the intussusceptum Gentle pressure on the apex will eventually lead to reduction though possibly the serous coat of the ensheathing layer may give way at one or two places While the pressure and manipulation of the intussusception is being continued the gentlest traction on the entering intestine is helpful and permissible Strong pulling never does good and may

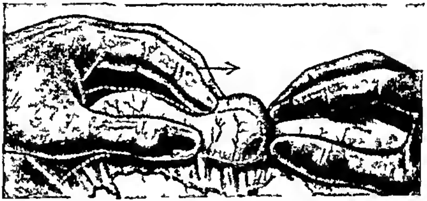

Fig 452 —Reduction of intussusception by gentle squeezing (left hand) and gentler pulling (right hand)

seriously damage the bowel Reduction will be complete when the appendix is free to the base of its mesentery or in other parts of the bowel when the dimple on the outer wall is pressed out The intestine is examined for injuries to the serous coat any necessary repairs are done and the parts returned to the abdomen In intussusception about the cæcum the commonest site the appendix after reduction may look very much congested or even be quite black from hæmorrhagic infarction If the child is in good condition such an appendix may be removed but this step is not really necessary for wonderful recoveries are the rule If after reduction the involved area shows signs of gangrene at isolated spots generally small black areas with lustreless serosa these may be sewn over with safety or if the condition is doubtful the suspected section may be withdrawn from the abdomen fastened in the wound covered with green protective and a warm moist dressing applied If in twenty four hours or less the parts have recovered they may be replaced within the abdomen

while if they do not recover a fæcal fistula will result The parietal incision is closed with continuous suture of the peritoneum and through-and-through silkworm gut sutures for the remainder, the stitches being placed half an inch apart

Complications—In certain cases it may be impossible to reduce the intussusception, and in others, where reduction has been possible, the gut may have been so damaged, either by its long strangulation or in the attempt at reduction, that its viability is doubtful What course should be adopted?

1 *A fæcal fistula may be made in the intestine proximal to the intussusception*—This method has little to recommend it, as it leaves the intussusception unreduced or introduces a dangerous complication It should only be done as a last resource in a patient too ill to stand any more time-consuming method The spontaneous cure of intussusception by sloughing of the intussuscepted part which is subsequently passed, is so rare that very few surgeons have seen a case, and the few recorded examples are almost legendary

2 *Short circuit by lateral anastomosis*—This method theoretically has the same disadvantages as the first method for it leaves the intussusception untouched, and in addition takes time which might be better employed in carrying out resection None the less it has proved very successful and is much safer than resection in infants If the intussusception appears to be in a condition of impending gangrene, or if its condition is doubtful, it should be wrapped in omentum after the anastomosis has been made It is also wise to bring a rubber drain from the neighbourhood to the surface

3 *Resection of the affected area*—This method takes a longer time than can be safely spent on abdominal operations in most babies and has been followed by a very high mortality In older children and in adults it is the method of choice It generally involves a resection of the ileo-cæcal angle with part of the ascending colon and restoration by end-to end union This operation has no outstanding difficulties especially in a patient who probably has a long mesentery, but it cannot be done very quickly, and is not usually undertaken until some time has been spent in attempts at reduction

The operation is, however, perfectly justifiable, and is often considered the best way out of a difficulty, but a high mortality must be expected

Resection may be carried out through an incision in the ensheathing layer (Jessett, Barker) This method, which was described in the last edition, is an attempt by the surgeon to imitate Nature's cure of intussusception by the sloughing and separation of the intussusceptum I have never carried out this plan and am not persuaded that it possesses any outstanding advantages

Choice of operation.—Whenever it can be readily carried out reduction is always the best plan Should it prove impossible, or should much damage be inflicted on the intestine in the process, short

circuiting by lateral anastomosis with omental protection of the involved bowel is the best course to adopt in children up to about 10 years of age In older subjects resection holds out a good prospect and can be employed with confidence

CHRONIC INTUSSUSCEPTION

This condition is very rare and is usually met with in older children or adults It may be possible to effect reduction safely but the patients are often suffering from the toxæmia of chronic intestinal obstruction and in these circumstances a two stage operation holds out the best prospect When the small intestine is involved lateral anastomosis followed in two or three weeks by resection, will be the correct procedure In the large intestine the first stage should be drainage of the bowel by cæcostomy and later resection of the involved segment

INTUSSUSCEPTION IN ADULTS

This is commonly produced by a bowel growth or an inverted Meckel s diverticulum

After reduction the causative factor can usually be demonstrated and must be dealt with As a rule, bowel resection will be indicated according to the rules for dealing with this matter (Chap XX) When a diverticulum is the cause it may be everted in the process of reduction of the intussusception If the point of attachment to the bowel is narrow, the diverticulum alone may be excised care being taken to close the resulting incision in the transverse axis of the bowel in order to avoid the formation of a constriction Should the base be very wide or the attachment be on the mesenteric side the portion of bowel bearing the diverticulum should be resected continuity being restored by end to-end union If the diverticulum does not become everted on reduction of the intussusception and the bowel is in good condition its lumen may be opened and the diverticulum ligatured off and removed like a polypus, the outer peritoneal dimple being oversewn Lembert fashion In other circumstances resection of the parent bowel will be the safest course

Results.—Intussusception although attended with a grave mortality shows on the whole better results than any other form of acute intestinal obstruction This is undoubtedly due to the fact that diagnosis is relatively easy and cases are submitted to operation promptly for here, as in all cases of intestinal obstruction the result depends almost entirely on the interval elapsing between onset and operation So many factors affect the issue that it is impossible to say what the minimum mortality should be Delay in operating age of the patient resistance to shock the anæsthetic are all points affecting the question apart from the condition found and the difficulties encountered Resection up to three years of age has proved a very serious proceeding, with a mortality approaching 100 per cent, but this reproach should be ascribed to late intervention rather than

to poor technique In the late Mr Carson's series of 40 cases there were 6 deaths, a mortality of 15 per cent One was colo-colic intussusception in a patient of 36 years, due to a polypus, another had an intussusception starting at a Meckel s diverticulum, and 2 required resection, so that of this list only 2 uncomplicated cases died

Many authors give widely different figures Clubbe, 100 cases, mortality 37 per cent, Ladd, 20 cases, mortality 45 per cent, Peterson, 19 cases, mortality 48 per cent, Wickmann, 223 cases, mortality 66 per cent But the figures are of little value without a knowledge of the circumstances attending each case

The mortality of operations for acute intussusception in children in these days (1942) is probably in the neighbourhood of 20 per cent

It is said that the *risk of recurrence* is so great that no operation for intussusception is complete unless steps have been taken to prevent it This is not the general experience, indeed, in my own experience of many years, only one recurrence took place among patients of the ordinary infant type, where the intussusception is believed to be due to disordered peristalsis It therefore seems fair to conclude that in children no special precautions to guard against recurrence are indicated In cases where there is a definite pathological cause, e g a polypus, a Meckel's diverticulum, a mass of glands at the ileo-cæcal angle, or a growth of the ileo-cæcal valve or in the colon the cause must be dealt with But these cases occur in older patients, when there is a reasonable chance of recovery from an extensive operation

VOLVULUS

Volvulus of the small intestine is extremely rare The condition usually involves the whole mass of small bowel, and the exact diagnosis is only made on exploration The treatment is to undo the twist after the abdomen has been opened Very few cases recover

Volvulus of the large intestine, on the other hand, is not so very uncommon It is practically confined to the cæcum or the sigmoid flexure, the latter being by far the more frequent site It occurs generally in adult life, and gives rise to a severe form of acute obstruction with marked local distension In many cases it is found in association with a mild degree of so-called congenital idiopathic dilatation of the colon The rotation of the cæcum is more limited than that of the sigmoid, rarely exceeding a quarter-turn, while the sigmoid may be rotated through a whole turn, or even more

Volvulus of the cæcum.—The abdomen should be opened in the median subumbilical line, even if the diagnosis is certain beforehand The incision should be free, so as to allow accurate observation of the twist and easy manipulation If possible, the whole mass should be lifted out of the abdomen The twist is generally clockwise, i e from the patient's right to left, and after inspection to note its direction it must be systematically untwisted, the mass being taken between the two hands and rotated in the reverse way If it is impossible to see which way the twist goes, a tentative unwinding should be done from

left to right when it will soon be evident whether it is being unwound or not When the volvulus has been undone some step must be taken to prevent recurrence to which there is a definite tendency though perhaps more in the sigmoid than in the cæcum owing to the thickening which is so often present in the sigmoid mesocolon Not infrequently it is found that a band of adhesions crosses the anterior surface of the colon at the point where the cæcum was twisted and this band requires division or removal Recurrence is prevented by sewing the cæcum into the right iliac fossa the sutures passing through the outer longitudinal band (or even through the anterior if there is a marked tendency for the cæcum to fall towards the midline) and fixing the cæcum to the peritoneal reflexion on the posterior wall of the false pelvis If the cæcal distension does not disappear after reduction of the volvulus it may be punctured and its contents evacuated the puncture being closed by suture or converted into a small cæcostomy

Volvulus of the sigmoid—Treatment is carried out on the same lines Here again the twist is probably from the patient s right to left but the distension is more extreme and thickening of the mesosigmoid often makes reposition more difficult and recurrence more likely The incision in the median or paramedian subumbilical line must be a long one as it is desirable to get the whole mass outside the abdomen Sometimes distension of the involved loop is so extreme that this is obviously impossible In such a case the bowel must be opened on its summit and the contents evacuated the greatest care being taken to safeguard the wound The mass having been lifted outside the abdomen the twist is unwound as described above Gangrene of the loop would demand excision but this is rare

Some of these cases look very complicated but the only way is to unwind the twist when the most involved looking mass will straighten out *if methodically rotated in the right direction* When after reduction the loop is found enormously distended congested and sodden a small colostomy should be made into the summit A Paul s tube is tied in and the area is sutured to the middle of the parietal incision Patients sometimes get so much relief from the colostomy that they are content to keep it permanently but of course it can easily be closed by suture if desired To prevent recurrence the whole loop may be excised or its summit may be sutured to the abdominal wall or an anastomosis may be made between the upper and lower limbs

But recurrence occurs despite the measures that may have been taken to prevent it colectomy of the sigmoid loop is then the correct treatment preceded for greater safety by temporary cæcostomy

GALL STONES AND FÆCOLITHS

These concretions may become impacted in any part of the intestine but the usual site is the ileum within 2 ft of the ileo-cæcal valve They are usually safely voided if they reach the colon though impaction

in the large bowel may occur (*vide infra*) Sometimes the calculus is arrested by a pathological stenosis (usually new growth) and there is a specimen in the museum of the Prince of Wales s General Hospital consisting of a gall stone as large as a hen s egg impacted in a stricture due to cancer of the splenic flexure

In this form of obstruction early operation is most important the high mortality is almost entirely due to late intervention and not to any difficulty inherent in the operation or after-care

The necessary intervention can usually be carried out with local anæsthesia and as the patients are often elderly and in poor condition this is a considerable advantage The abdomen should be opened by a median incision below the umbilicus With a couple of fingers introduced into the cavity the foreign body is usually readily located though it may he necessary to trace the intestine up or down in order to find the exact site of obstruction The treatment then consists in withdrawing the intestinal coil containing the foreign body from the abdomen inspecting it to be sure that it shows no sign of pressure necrosis and if it is sound gently pushing the stone upwards until it reaches a portion of the intestine less implicated in the obstruction Very often the stone cannot be moved in the intestine and the latter must be incised at the point of impaction The intestine is gently clamped a little distance above and below the stone and the wound having been guarded with scrupulous care a longitudinal incision is made on the antimesenteric border over the foreign body and large enough to allow the stone to be extracted without bruising the edges of the incision The opening in the gut is closed in the transverse axis of the bowel to avoid the risk of narrowing the lumen It is not necessary to drain the intestine In rare cases the gut suffers from pressure necrosis and enterectomy must be performed

When gall stone ileus is met with there is often an internal fistula between the gall bladder and some part of the alimentary canal There may also be one or more calculi in the gall bladder itself These pathological considerations raise the question of interference with the gall bladder either at the time the obstruction is dealt with or as a deliberate later step The answer is supplied by the knowledge that recurrent obstruction or subsequent gall stone attacks are very rare There is the further consideration that patients suffering from gall stone ileus are often very ill and any extension of the operation would be an unwise proceeding

Results —This condition often occurs in old and feeble women who are poor surgical risks and although the operation is easy and can be done very rapidly there is a mortality of over 50 per cent This high mortality is largely due to delay in diagnosis and operative treatment I had three deaths in thirteen operations for this condition In one case the calculus which was impacted in the colon measured 7 inches in circumference and weighed 5 oz The patient recovered *

* *Brit Journ Surg* 1932, xx No 77 p 28

ENTEROSTOMY

This is the name given to the operation for draining the small intestine It may have to be employed when the patient is desperately ill from intestinal obstruction, with an enormously distended abdomen but without indication as to the site In such conditions a blind enterostomy will overcome the immediate necessities and may assist in carrying the patient on to a stage at which a complete operation for the location and removal of the cause may be carried out It may also be employed in case of paretic obstruction to overcome the great tension in the gut, and to provide the means for treatment by irrigation Lastly, an enterostomy of the lowest part of the ileum has been used as the most effectual way of resting the colon in extreme colitis These measures are always temporary, and when the opening has fulfilled its purpose it must be allowed to close, though this requires operative interference An opening into the small intestine for the purpose of feeding the patient is quite a different measure and is known as jejunostomy (*see* p 745) The main disadvantage of the operation of enterostomy is that the opening may develop into an intestinal fistula which, if it happens to be high in the bowel, will cause so great a loss of intestinal contents as to lead to rapid starvation and death Wherever situated, there is the risk of constant discharge of intestinal contents gravely interfering with nutrition and always causing troublesome local skin irritation For these reasons it is most important to endeavour so to plan the operation that the purpose of draining the intestine can be carried out with the chance of subsequent fistula If there is no pre-existing incision which may be used, the abdomen should be opened in the right iliac fossa, for in this situation it is more likely that the lower part of the small intestine will be encountered An incision only big enough to allow a distended coil of intestine to be withdrawn is required A rubber catheter, size No 12, is then fixed in the bowel after the method of Coffey This operation is strictly comparable with that surgeon s technique of implantation of the ureter into the bowel the catheter in the enterostomy taking the place of the ureter. A longitudinal incision 2½ to 3 inches in length is made along the summit of the loop and is carried through the muscular coats down to but not including the mucous membrane The muscular coat retracts and the mucous membrane bulges into the incision A small opening just large enough to allow the catheter to be passed into the lumen of the bowel is made at the lower end of the incision At this point the catheter is fixed to the wall of the bowel with a stitch to guard against accidental withdrawal If the aperture in the mucous membrane is too large, a purse string may be so placed as to draw the edges up around the catheter The latter is then laid along the incision in the sulcus provided and of course lying on the outer surface of the mucous membrane The muscular coats are then drawn together over the catheter either by a series of *intermitted* sutures or a continuous stitch If necessary one or two Lembert sutures fix

the peritoneum more securely into position The extremity of the catheter should be plugged and passed through a hole in the great omentum so that the latter intervenes between the small intestine and the parietes The catheter is then brought out through the parietal incision, and the bowel wall, with the omentum, is anchored to the parietes by one or two catgut stitches at the point where the catheter comes through the wound In this way the intestinal contents can be drained on to the surface, the bowel can be irrigated or fluids can be fed to the intestine When the enterostomy is no longer required, but not sooner than a week after being made the catheter may be withdrawn and in most instances the opening will close of its own accord that is supposing the cause of the obstruction has been dealt with or has spontaneously disappeared Before the plan of interposing the omentum between the intestine and the parietes was adopted, it was usual for the opening to remain patent so that the intestinal mucous membrane protruded on to the skin surface In those circumstances a troublesome intestinal fistula resulted which could only be closed by operative interference It was necessary to separate the intestine from the parietes to expose the margins of the opening and to suture it in a direction transverse to the axis of the gut Sometimes the whole loop had to be removed, a formal enterectomy being carried out The skin irritation which often develops round the enterostomy may be relieved by painting with white of egg, or by a gauze dressing soaked in milk

CHAPTER XX

ENTERECTOMY AND INTESTINAL ANASTOMOSIS

By G GREY TURNER

MANY conditions make it necessary to resect portions of the small or large bowel and to restore continuity or to make anastomosis to short circuit an obstruction

The indications for many of these procedures will be found in the appropriate article and here it will be enough to describe the different methods by which the resection or anastomosis may be performed

In the early days of intestinal surgery the fear of leakage and the feeling that the suture line required support led to the use of many contrivances varying in complexity from Murphy s button to the absorbable bone bobbin How much these mechanical contrivances assisted the progress of intestinal suturing and how far they delayed the coming of anastomosis by simple suture is a moot point But the day of these aids is over and they will not be described in this work Nevertheless intestinal surgery owes a deep debt of gratitude to their inventors and particularly to Murphy whose ingenious button with all its risks and disadvantages made intestinal anastomosis an easy and even a relatively safe procedure and did a great deal to establish intestinal surgery in the comparatively satisfactory position which it now occupies

At the present time intestinal anastomosis is invariably carried out by direct suture without mechanical supports of any kind Various machines of great ingenuity have been invented to reduce the labour of suturing with ordinary needles manipulated by hand or holder These pieces of complicated apparatus have not yet become popular with surgeons in general and it can be stated with confidence that they are quite unnecessary are limited in actual application and lack the precision of the ordinary needle carefully and skilfully guided by hand

GENERAL CONSIDERATIONS

As the contents of the intestinal tract are contaminated with micro-organisms and as it is impossible to sterilize the bowel by any form of preliminary treatment it follows that no operation which involves opening the lumen can be performed strictly aseptically There is therefore in all intestinal operations a risk of failure due to sepsis In dividing the mesentery and securing bleeding points injury is done to the blood supply of the tissues to be united in dividing the intestine it is impossible to avoid soiling the future suture-line In suturing the passage of the needle in the all-coats suture carries infection with a risk of ulceration healing by granulation and subsequent stricture

The Lembert suture reduces the risk of a leak to a minimum wherever there is a serous coat, but at the point where the leaves of the mesentery separate to enclose the bowel there is a space uncovered by serosa, very narrow, it is true, in the small intestine, but so wide in some parts of the ascending and descending colon that at these points some surgeons consider end-to-end anastomosis unjustifiable

With every care there is a risk of infection within the mesenteric angle, and in experimental work this has been shown to occur invariably Soresi * after "many hundreds of end-to end anastomoses performed on animals with every method known using all possible precautions," finds "that the mesenteric space (angle) was always highly infected from the very moment the anastomosis had been performed up to eight and, at times, many more days after," and that 'leakage occurred much more often when the thermo-cautery, carbolic acid, or any supposed sterilizing agent was used than when the gut was simply severed with knife or scissors' He maintains that failure would always occur from this cause were it not that the infective material between the leaves of the mesentery (in the mesenteric space or angle) breaks through the point of least resistance i e the suture-line joining the two portions of the anastomosed intestine, and drains into the intestinal lumen Nevertheless a large proportion of the cases do perfectly well making not only good immediate but lasting recoveries.

So-called aseptic methods of anastomosis —By the use of ingenious clamps or other forms of apparatus, attempts have been made to carry out intestinal anastomosis either without exposing the lumen (Frazer and Dott) or with a minimum of exposure (Seton Pringle and Rankin)

In my opinion these plans are founded on a misconception of the factors governing the results If failure occurs, it is either due to interference with the gut in an unsuitable condition as the result of infection from obstruction, or to defective blood supply so that there is necrosis at the suture line or it is due to careless application of the sutures None of these factors can be controlled by mechanical aids

Suture material —For many years I have used nothing but fine chromicized catgut, and this has proved entirely satisfactory, size 8/0 is selected for the inner sutures and 3/0 or 6/0 for the outer layers Silk or linen thread are quite reliable but, as they do not absorb, the inner suture, at all events, is probably always extruded into the lumen of the bowel by a process of ulceration and this may take a longtime, (Fig 453) In the experimental animal silk is attended with minimal reaction but catgut has the advantage that having served its purpose, it can be relied upon to absorb safely

Needles should be rounded and of just such a size as comfortably to carry the suture material The eye-less atraumatic pattern is ideal but extravagant, and the accumulated experience of many years of successful intestinal surgery has shown that it is not essential

* *Ann Surg* June 1919 lxix 618

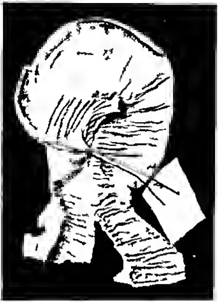

Fig 453 —A linen thread suture hanging loose in the intestine 8 months after its insertion at an operation for intestinal anastomosis

(From G Grey Turner Macewen Memorial Lecture, Jackson Son & Co Edinburgh)

The principles which should guide the surgeon are (1) He must recognize that no intestinal anastomosis of any sort ought to be attempted in the presence of established obstruction In this condition the bowel is distended and the wall is œdematous from infection and after any interference is liable to paresis When obstruction is incomplete or in a very early stage and the surgeon is tempted to do a *complete* operation rather than be content with preliminary drainage and a second stage resection it is essential to provide a safety valve by means of some type of temporary enterostomy The conditions are different in acute strangulations where the blood supply is completely cut off from the bowel Then the acute symptoms demand interference before mechanical obstruction of the lumen of the bowel becomes an important factor and excision of large portions of intestine may be required (2) It is essential that any operation which involves opening the bowel should be done only when it can be brought outside the abdomen In the small intestine there can scarcely ever be any difficulty, but in the large it is essential to secure this by mobilization The recognition of this factor has been of great value in the development of the more successful operations for resection of the large bowel which are now usual (3) It is also important to see that the cut edge of the bowel is not flooded with intestinal contents during the application of the sutures and for this reason it is the rule to use some type of restraining clamp This should be quite light and have a good spring in the blades so that they may attain their object while injury to the wall of the bowel is reduced to a minimum Usually the blades are protected by rubber, but if the clamps are sufficiently light this is unnecessary Except when it is necessary to crush the bowel to make a groove for an occluding suture it is never wise to employ a heavy clamp (4) Most cases in which failure of union occurs are due to some defect in the blood supply of the edges of the bowel at the site of the junction This is so very important that the surgeon should not rely on preconceived ideas of what the blood supply should be as indicated in textbooks of anatomy but should satisfy himself by inspection and palpation of the mesentery that the blood vessels are healthy and pulsating right up to the point chosen for the anastomosis

In order to be quite sure it may be necessary to remove the clamps and actually see the bowel margin bleed Occasionally the arrangement of the gauze packing or the kinking of the bowel over the edge of the abdominal incision is enough to account for some temporary interference with the vessels and the surgeon must take care not to be misled in this way (5) Further, there must be no tension and the bowel ends must lie snugly together without the least drag on the sutures So far as the actual method of union is concerned, an anastomosis can always be made safely by simple suture in two layers, one continuous running stitch taking all the coats so as to make the union hæmostatic and watertight and the second to bury the first by approximating the peritoneum Lembert fashion At any point where the bowel is uncovered by peritoneum an attempt should be made to protect it further by the epiploic appendices or omentum used as grafts (6) Finally, if there is any doubt about the security of the anastomosis, it is essential that the bowel above it should be temporarily drained so that distension will not add an additional factor to strain the union In these circumstances it is also wise to provide a track from the neighbourhood of the anastomosis through the parietal incision so that leakage can readily find its way to the surface and be less likely to give rise to peritonitis

ENTERECTOMY AND END-TO-END OR AXIAL ANASTOMOSIS

Small intestine.—Having decided on the portion to be removed the surgeon lifts the affected loop out of the abdomen with a sufficient length of healthy intestine on each side (Fig 454) The general cavity of the peritoneum is protected by large swabs wrung out in hot saline The intestinal lumen above and below is controlled by applying light clamps which do not perforate the mesentery, or by passing one end of a fine rubber tube through a hole in the mesentery, twisting the ends together, and retaining them with a pair of pressure forceps At the points selected for division of the intestine an opening is made in the mesentery by blunt dissection as near the gut as possible, and these openings are enlarged as far towards the root of the mesentery as may be required The mesentery on both sides of the proposed line of division is caught in a succession of artery forceps as the section proceeds The actual division is most conveniently and cleanly made with scissors In making this division it must be remembered that the mesentery is like an open fan, the attachment to the posterior abdominal wall being only about 6 in long, while the intestinal attachment is about 22 feet, so that in all but very wide resections the incisions tend to meet at a point near the root and enclose a triangular piece of mesentery It is possible, when the mesentery is not loaded with fat, to start the incisions as near its root as the pathological condition demands and to make the section towards the gut Or the division may be made more or less parallel with the portion of intestine to be

removed if it is not essential to take away the lymph nodes Whatever method is to be adopted, the mesentery should, if possible, be dealt with first in order to avoid the risk of infecting it from the bowel The worst possible surgical fault is to divide the intestine and *continue into the mesentery with the same knife or scissors* Sometimes it facilitates the operation to divide the bowel before the mesentery, and there can be no objection to this plan provided that fresh instruments are used for the mesentery and that the divided ends of the bowel are covered over with gauze swabs

The vessels may either be caught by a series of encircling ligatures passed through the mesentery with a needle or forceps before its division, or sections may be taken up in a series of artery forceps and

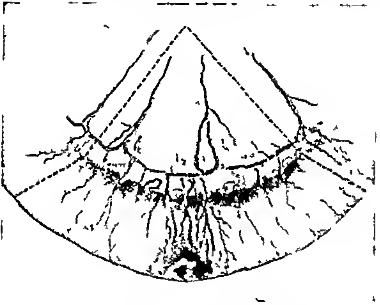

Fig 454 —Intestinal resection line of division of gut and mesentery.

subsequently tied It is not necessary to interlock the ligatures, nor are special clamps required for dealing with the mesentery, but it is essential to use forceps whose blades meet along their whole length Otherwise, portions of tissue are apt to elude the grasp and, in consequence, vessels retract and may be a source of troublesome or even serious bleeding In dealing with the fat mesentery it is important that an adequate amount of tissue should be left beyond the bite of the forceps, for it is in these cases that the vessels are especially apt to retract and escape the ligatures If this accident happens, with formation of a spreading hæmatoma, extravasation rapidly occurs and must be dealt with at once By far the best plan is to divide the tissues over the hæmatoma in the course of the vessels and to squeeze away the extravasated blood so that the retracted and bleeding vessels can be seen and individually caught and tied

The division of the mesentery having been completed a large gauze swab is passed through the gap The resection is then proceeded with

Nowadays practically every intestinal anastomosis is carried out by the method of simple suture in not less than two layers Light clamps are used and the bowel ends held in apposition while the posterior peritoneal surfaces are secured by the Lembert stitch (Fig 455)

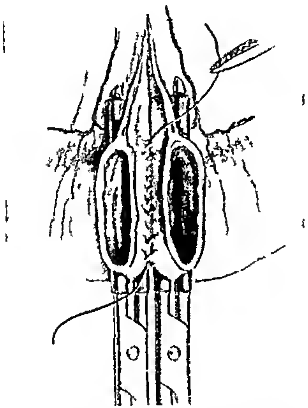

Fig 455 —Intestinal anastomosis end to end Bowel ends held in apposition and posterior Lembert suture being applied

This is commenced at the antimesenteric border and is continued across the whole distance of the bowel After this is completed the end of the suture is left long with its needle and is covered by gauze The all-coats through and through suture is then commenced in the same way and is carried right round the bowel In order not to absorb too much of the bowel wall when the suture is tightened it is wise to interrupt it at about three points by locking or actually tying the stitch and starting afresh After the bowel has been encircled the posterior Lembert suture is carried round the front to the point where it was first commenced and is there tied to the end with which it started (Figs 455–458) Any point where the apposition is not

very accurate, or where there is an oozing area may be supported and covered over by an additional interrupted stitch The mesenteric angle where the leaves separate to enclose the bowel is undoubtedly a danger-point but if great care is taken to see that the corresponding edge of the bowel is well inverted into the lumen by the all-coats stitch, no harm is likely to result A carefully applied Lembert stitch further adds to this inversion and, passing continuously from the front to the back of the bowel tends to draw the mesenteric leaves

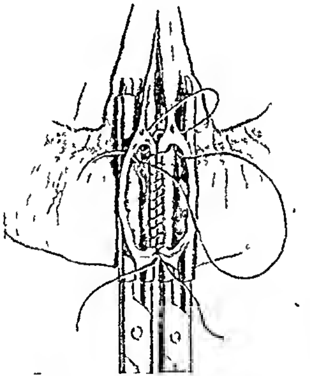

Fig 456 —Intestinal anastomosis end to end
The all coats suture being applied

together The area is further supported by closing the gap in the mesentery It is usual to leave the clamps in position until all the sutures have been inserted and tied, but they may be safely loosened at any time during the operation if (1) the surgeon is anxious to verify the adequacy of the blood supply, or (2) the clamps are too near the suture line and must be readjusted They may be removed as soon as the inner all-coats suture has been applied, but they are convenient holders for the bowel and are usually left to the later stages

The anastomosis is completed by uniting the cut surfaces of the mesentery by a running suture In sewing together the cut edges of the mesentery there is a risk of pricking a vessel, and if this happens a

hæmatoma forms between the leaves of the mesentery and may spread with great rapidity To obviate this risk Littlewood suggested that opposing points of the mesentery should be picked up with pressure forceps and that these points should be tied together and this is the method which I use Most surgeons taking the greatest care to avoid vessels prefer joining the edges with a continuous suture which excludes the risk of leaving even a small aperture

If clamps are not used the procedure is the same but the sutures

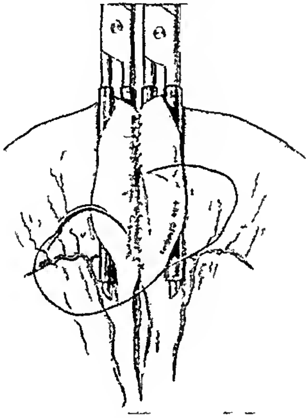

Fig 457 Intestinal anastomosis end to end
The anterior Lembert suture

are more difficult to apply owing to the mobility of the parts and the apparent surplus of mucosa To meet the difficulty it is usual to insert two guide sutures (one at the mesenteric the other at the antimesenteric edge) traction upon which will approximate and stabilize the intestinal ends These guide sutures should be sero muscular only, and may be removed as soon as the posterior sero muscular suture has been applied Whether or not clamps are used it is convenient to hold the edges in contact by means of some type of fine catch forceps These have been omitted from the illustrations in order not to obscure the essential details The method described is satisfactory and convenient but I usually employ the technique

which is used for anastomosis in the large bowel and is described and illustrated on p 918 The posterior mattress sutures provide a good way of dealing with the mesenteric angle and can be relied upon to draw that part of the bowel into good apposition and ensure that the mucous membrane is safely turned towards the lumen (Figs 458–460) Of course the all-coats continuous and Lembert sutures are used in addition

Some additional points —The object of the continuous through and through all coats suture is to make a water tight union with control of the vessels The stitch should be applied from the lumen of the bowel for in this way the edges tend to be inverted and there should

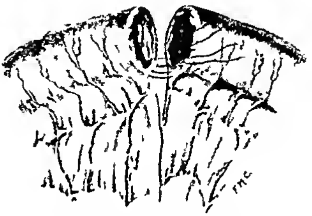

Fig 458 —End to-end anastomosis of mattress sutures across mesenteric angle as a first stage

be little or no pouting of the mucous membrane on the outer surface But to place this suture in this way is not essential and some surgeons advise that the stitch should be an external overhand running suture The one essential is to secure good hæmostasis with secure apposition but without narrowing the bowel at the site of the anastomosis The distance between each needle puncture should not be more than a quarter of an inch and the distance from the cut edge should be a little less It is important that the suture should include the whole thickness of the bowel wall Sometimes the excess of mucous membrane makes the placing of the needle a little difficult but the surgeon must not be tempted to cut mucous membrane away, as it is essential to have the submucous layer well protected by this excess The Lembert sutures may be interrupted though the small intestine lends itself to the continuous suture But when the latter has been completed there must be no hesitation in putting in an additional interrupted stitch here and there if pouting mucous membrane or *oozing* points indicate additional protection

Except in cases of injury where there is much bruising of the bowel omental grafts are never necessary in small intestine suture It is

often stated that single layer suture is sufficient in the small bowel, but it is foolish not to adopt the additional safety that follows good peritoneal apposition, which may be so readily secured by a Lembert suture, even if only inserted at a few points along the line of anastomosis It is not necessary, nor indeed is it an advantage, to divide the bowel with the diathermy needle or the cautery or to attempt sterilization of the exposed mucous membrane by the application of pure carbolic It is much better to regard the lumen of the bowel as an infected area and to protect surrounding parts from contamination

When the bowel-wall is exceedingly thin, great care is necessary to avoid entering the lumen when placing the Lembert sutures In these

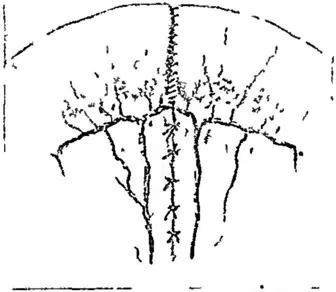

Fig 459 —End to end anastomosis in small intestine completed with gap in mesentery drawn together

circumstances an adequate hold can often be best secured by passing the needle through the peritoneum parallel to the line of anastomosis

Many problems in connection with end-to-end anastomosis have still to be made clear We do not know how much of the gut-wall may be infolded without risk of an immediate or late obstruction, nor whether a wide infolding gives a sounder suture line than otherwise Halsted* said that the infolding of the wall may be great enough to fill the lumen, and yet not cause obstruction The fate of this diaphragm is doubtful does it persist, does it gradually or even rapidly unfold itself as the sutures absorb, or does it slowly separate or ulcerate away ? Most surgeons of experience must agree that an end-to-end anastomosis seen after a lapse of time does not show any diaphragm, nor is there a fibrous ring such as might be expected if the suture line healed by ulceration and granulation

* *Journ Exper Med* 1912 xv 218

End-to-end anastomosis in the colon—Difficulties are said to occur owing to the thinness of the intestinal wall its poor blood supply compared with the small intestine and the presence of the appendices epiploicæ which make a perfect sero muscular suture line more difficult

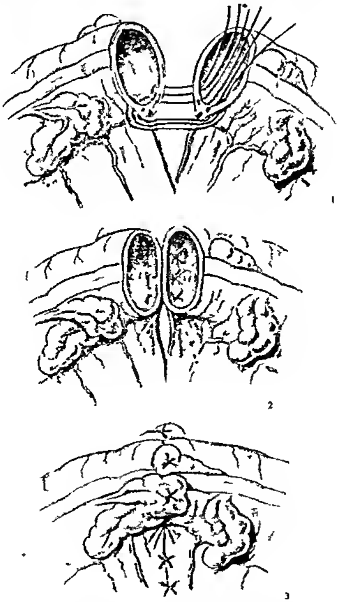

Fig 460—**End to-end anastomosis in the colon**

1 Approximation by posterior mattress sutures. 2. The sutures tied safely inverting the mesenteric margin 3 Anastomosis has been completed by insertion of the all-coats and Lembert sutures. The illustration shows the way the anastomosis is supported by stitching the neighbouring appendices over the suture line

It is sometimes advised that the appendices should be removed from near the end of the bowel before placing the sutures but this is a mistake for they are very useful as supports for the suture line and are also an additional source of blood supply Their bases may be partially detached and extra fat may be dissected back from the suture line but should not be removed

End to end anastomosis is safest where the serous coat is complete but at the same time it can be done where a lateral anastomosis is impossible owing to want of material A convenient and efficient plan is to begin by approximating the mesenteric side of the gut by a series of mattress sutures (Fig 460) These turn the mesenteric part of the bowel well towards the lumen so that it can be safely taken up by

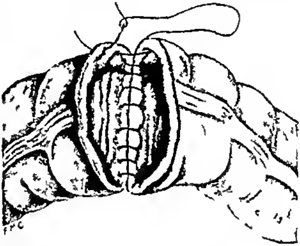

Fig 461 —Continuous all coats suture passed from the lumen of the bowel

the all coats continuous stitch which is next applied This is commenced just to one side of the mattress suture and is continued across where they lie and then all round the bowel to finish off where it began (Fig 461) It is wise to lock or even interrupt this suture at two places but this presents no difficulty The serous coats are best apposed by interrupted sutures as a continuous stitch may interfere with the blood vessels and the appendices The bowel must be rotated so that the posterior sutures can be applied Finally, the anastomosis is protected and strengthened by using the epiploic appendices as shown in Fig 460 It is well to reinforce an end to end anastomosis in the colon by using every available epiploic appendix in this way These must be fixed in position by a stitch here and there but great care must be taken not to occlude the vessels in the appendices If there is the slightest doubt about the integrity of the suture line or if the intestine is softened or friable from previous distension or infection it is essential to bring a rubber tissue drain from the region of the anastomosis to the surface In cases where this is likely

to be necessary the proper placing of the incision as discussed later (Fig 477 p 940) is very important If the anastomosis is low enough down as in the iliac or pelvic colon a long tube may be passed from the anus well up beyond the anastomosis If this is not possible a tube should be left through the sphincter to prevent distension of the rectum

LATERAL ANASTOMOSIS

The supposed advantage over end to-end anastomosis is that the mesenteric angle is eliminated so that the operation can be safely performed even in parts of the intestine where the serous coat is not complete It also allows union without difficulty between portions of bowel of different sizes Its disadvantages are that it takes a little longer owing to the necessity of closing and over sewing the open ends of the intestines to be anastomosed it requires a greater length of intestine and there is a tendency for the proximal blind end to enlarge as the result of the *vis a tergo* (I have known a case in which this dilated blind end burst as the result of a fall) As a step in short circuiting lateral anastomosis is an established procedure and the indications will be considered in connection with intestinal exclusion After enterectomy lateral anastomosis should be made isoperistaltic not because it makes any difference in the passage of the intestinal contents but the parts lie more naturally and the suturing is easier

The choice of a point for the anastomosis must be guided by the purpose of the operation For instance if the anastomosis is done after enterectomy is should be placed near the resection so as to make the blind ends as short as possible If done to short-circuit a neoplasm it must be placed at such a distance that it will not be likely to be implicated by the continued progress of the growth

Technique of lateral anastomosis —*The resection of the portion to be removed is carried out as for axial anastomosis and the two open* ends are closed In the small intestine this can be quickly and safely done by crushing the intestine at the point selected tying a silk or strong catgut ligature around the gut at the site of crushing and cutting away the portion to be resected The ligatured ends are then buried under a sero-muscular purse string suture which may be safeguarded by a further superimposed purse-string a mattress-stitch or one or two separate stitches The colon may sometimes be closed in the same way but it is wiser to use a deliberate double row of sutures the first all-coats the second sero-muscular For the actual anastomosis one half the circumference of each section of the gut at its antimesenteric border is picked up and controlled by an intestinal clamp The two surfaces to be anastomosed are then brought together each held in its clamp over a thick strip of gauze wrung out in hot saline solution the clamps being held side by side or tied together at the blade points and the hinges Two large flat swabs wrung out in hot saline are placed one on each side of the clamps and meeting at each end so that with the strip of gauze the area of

operation is shut off completely from the cavity of the peritoneum. The apposed coats of the intestine are then sewn together by a continuous Lembert sero-muscular suture for a distance of about 2 in.,

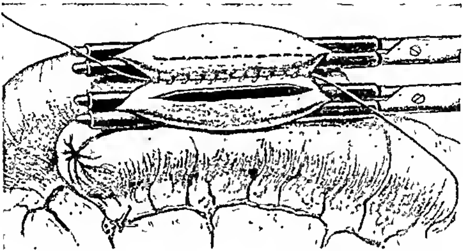

Fig. 462.—Intestinal anastomosis, lateral method: posterior sero-muscular suture inserted; one "cone" opened, line of incision in the other indicated.

the submucous coat being included. (Figs. 462–465.) This forms the posterior outer sero-muscular suture. An incision is then made parallel with and ¼ in. from the suture line through the serous and

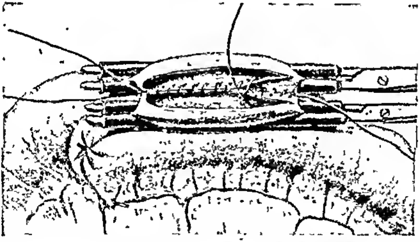

Fig. 463.—Intestinal anastomosis, lateral method: completing posterior all-coats suture.

muscular coats of the two portions of intestine, so as to expose the submucosa. This is picked up with dissecting forceps and incised for the full length of the incision, thus opening the lumen of the intestine. Doing this deliberately in two stages, i.e. exposing and then opening

the mucosa is of value in limiting soiling of the edges by the intestinal contents any intestinal content is wiped away with small gauze pledgets

Starting at the end furthest away ie at the end at which the

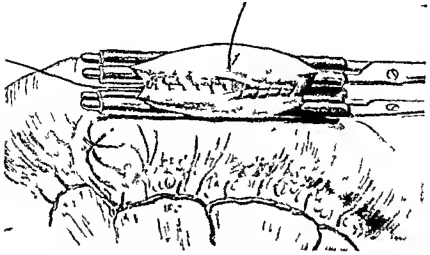

Fig 464 —Intestinal anastomosis lateral method application of anterior sero muscular suture

sero muscular suture started the contiguous cut edges are sewn together by an all coats through and through continuous catgut suture (Fig 468) which begins on the mucous surface of the right

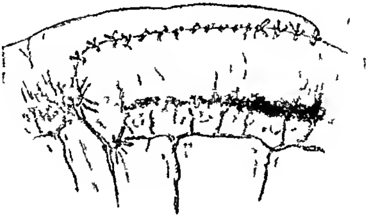

Fig 465 —Intestinal anastomosis lateral method anastomosis completed

opening and is therefore knotted on the mucosa This suture joins the contiguous posterior intestinal walls together and is knotted when the near end is reached The anterior all coats suture-line is then

done, the same thread being used, and the first stitch on the return journey being made by passing the needle from the mucosa of the left through all coats and crossing over to enter the right from without inwards A simple overhand continuous suture may be used for this row, the greatest care being taken that each loop falls vertically along the suture line, or, if preferred, the "in-and out" suture illustrated for end-to end anastomosis may be employed (Fig 468) When the far end is reached, the suture is knotted to the end left long at the commencement The sero-muscular suture is then resumed (Fig 464), the all coats suture thus being buried under the continuous Lembert suture When this reaches the far end it is knotted to the original end which was left long The clamps are removed and after the gauze strip has been slipped away, the suture line is inspected and any bleeding-points controlled Each blind end is then sewn to the proximal and distal portions of the anastomosed gut respectively and the gap in the mesentery is closed by a few points of suture (Fig 465) With one portion overlapping the other this gap in the mesentery is more potential than actual

OTHER ANASTOMOSES

End-to-side anastomosis.—This method of restoring continuity is used occasionally in small intestine anastomosis as in the Moynihan-

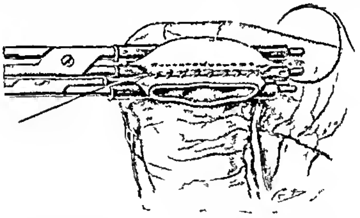

Fig. 466 —Intestinal anastomosis, end to side The posterior sero-muscular suture is applied Line of incision in colon shown

Mayo retrocolic partial gastrectomy, or the old Roux's entero-enterostomy *en Y* after gastro-enterostomy. It is more often employed in anastomosing the small and large intestine, as in ileo transverse colostomy after resection of the right colon, or in ileo-sigmoidostomy It is easily done, and does not often leak, but it has a theoretical disadvantage in the risk of axial rotation, though in practice that complication very seldom occurs

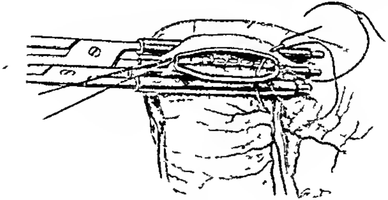

Fig 467 —Intestinal anastomosis end to-side beginning anterior all coats running suture

Taking as a typical example the *ileo-transverse colostomy* after resection of the right colon, the ileum will have been divided distal to a clamp and the open end of the transverse colon closed The anastomosis is then made with the transverse colon at a point where the intestinal wall will hold a suture well and where the intestines will lie snugly together The posterior tænia is generally chosen and is reached by raising the omentum and exposing the under surface of the colon A cone of the large bowel at the selected point is lifted into and controlled by a clamp The ileum is brought up, held in a clamp and, by giving the clamp a quarter turn to the right holding it in the right hand, the serous surface of the ileum is brought in contact with the selected portion of colon The two surfaces are united for the length of the diameter of the ileum by a sero-muscular continuous Lembert suture (Fig 466), the original knot-end being left long, and the suture again knotted at the end of the suture line and left with needle *in situ*

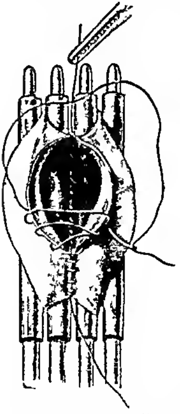

Fig 468 —Illustrating the "in and out" all coats suture in anastomosis

The colon is then opened by an incision parallel with and ¼ in from the suture line, and any contents of the open intestines are wiped away with small gauze pledgets A through and through all-coats suture is now applied sewing together the apposed coats of the two bowels (Fig 467)

A simple running suture will do for this the first knot and the loops being, of course, on the mucous surface (Fig 468) The first (sero muscular) suture is then resumed and the anterior Lembert finished burying the all coats suture line (Fig 469)

The cut edge of the mesentery is carefully united to the mesentery of the colon (Fig 470)

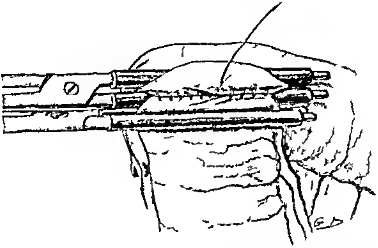

Fig 469 —Intestinal anastomosis end to side final suture anterior sero muscular

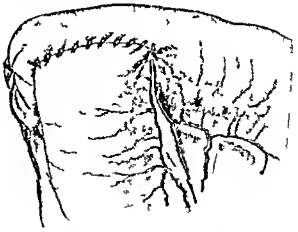

Fig 470 —Intestinal anastomosis end to side anastomosis completed

Side-to-end anastomosis.—This is a method of anastomosis which may be used in restoring continuity by ileo-transverse colostomy after resection of the right colon It is said to have the advantage over end to-side anastomosis that axial rotation is impossible, and that there is no risk of even temporary closure of the anastomotic opening as the result of œdema, and over lateral anastomosis, that there is

only one blind end and that a very short one which tends to empty itself by force of gravity The details of the operation do not differ from those already described for entero-anastomosis (Fig 471)

Anastomosis when the ends are of unequal size—This is often the case when the small intestine has to be united to the colon The situation may be met by resorting to lateral anastomosis or one of the methods of end to side union but the surgeon may prefer the axial method with all its advantages To enable this to be done the inequality may be overcome or much diminished by cutting the end of the small intestine obliquely or making an incision along its anti mesenteric border and trimming off the corners When this does not completely suffice further help can be obtained by modifying the

Fig 471 —Intestinal anastomosis side to-end ileo colostomy

application of the all-coats suture (*a*) by taking a rather larger bite of the end with the bigger lumen or (*b*) by taking two bites of this end to each one of the smaller end Where the disparity is very great it may be overcome by diminishing the larger end by suture in either of the ways represented in the diagrams (Fig 472)

Temporary enterostomy combined with resection—In the small intestine this must be avoided whenever possible If it is used there must be careful preparation and in the after treatment measures to restore the tone and contractility of the distended small bowel and the use of the principle of decompression by means of the Wangensteen or Miller Abbot tubes When it is felt at the time of operation that a safety valve must be provided an enterostomy may be made about a foot above the site of anastomosis by the technique described at p 906

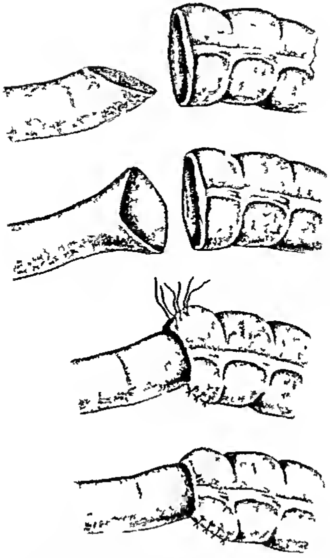

Fig 472 —Methods that may be used when the bowel ends are of unequal size For the sake of clearness most of the sutures are not shown

INTESTINAL EXCLUSION

The intestine is said to be ' excluded ' when the normal course of flow of the contents is diverted Exclusion may be partial or complete For instance if a lateral anastomosis be made between two portions of intestine on either side of an obstruction the exclusion is only partial and is generally called a ' short circuit If again the gut is cut across above and below the obstruction the part included between the two cuts is completely excluded Or if the gut above an obstruction is divided across and the proximal end anastomosed to the intestine below the obstruction, then a condition results which is called complete

unilateral exclusion So that exclusion may be described as (1) bilateral partial or short-circuiting (2) unilateral complete and (3) bilateral complete

Indications —One or other form of exclusion has been employed in many conditions either as a permanent treatment or as a first step in a two-stage enterectomy Of these conditions the chief are *obstructions* of various kinds and *fæcal fistulæ* The type of exclusion known as unilateral complete has also been used extensively for colonic stasis Short circuiting has a definite value in acute obstruction e g in mass obstruction by bands (*see* p 884) and in paralytic ileus in which the value of avoiding a fistula high up in the jejunum is obvious In organic obstruction of the colon e g in malignant disease an anastomosis may be done between the small intestine and the colon below the stricture (especially valuable in stricture of the ileo-cæcal valve or cæcum) or between colon and colon e g transverse to sigmoid in splenic flexure growths or cæcum to sigmoid in transverse-colon growths It is however in these operations for colonic obstruction that difficulties arise and it is well to have certain definite rules which can be applied to the various conditions met with especially as many of these operations are done in emergencies as a temporary measure to relieve obstruction before a radical operation can be attempted

Difficulties and contra indications —In operating for *fæcal fistula* it is important to remember that a simple short circuit is useless and that owing to reverse peristalsis a unilateral complete exclusion may also prove ineffective For instance suppose that it is desired to close a fæcal fistula in the cæcum which has occurred either as the result of gangrenous appendicitis or following a deliberate artificial anus for a temporary obstruction and that all attempts at closure by local operations have failed It is quite useless to do an ileocolostomy or an ileo-sigmoidostomy whether a lateral anastomosis or an anastomosis after division of the ileum be chosen In the former the intestinal flow is only partly diverted and in the latter reverse peristalsis will bring fæcal matter in the direction of the fistula which will continue to discharge though of course to a lesser degree

Bilateral complete exclusion is necessary for cure that is division of the ileum close to the ileo-cæcal valve a division of the colon beyond the fistula and a restoration of continuity with subsequent removal of the excluded intestine If the latter step is not considered wise the fistula must remain open to some extent to allow the escape of mucus which is constantly secreted and may lead to rupture of the cæcum unless an exit is provided (Fig 473 A)

In choosing a site for the anastomosis to restore continuity a point of special importance is to avoid *long blind ends* In for example a growth of the right colon causing obstruction but amenable later on to radical block resection the anastomosis of the preliminary exclusion operation must be so placed that a long blind end will not be left after the radical operation In such a case an ileo-sigmoidostomy

must not be chosen, as that would mean that the block-resection would leave a blind end consisting of half the transverse colon and the descending colon, which would be kept constantly full of fæcal material by reverse peristalsis This reverse peristalsis is the great disadvantage

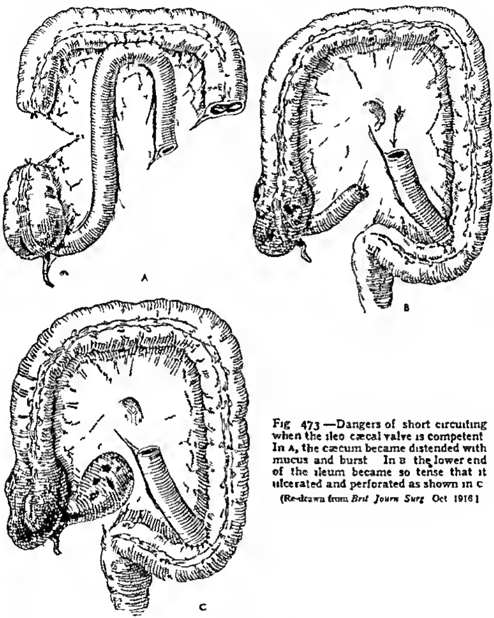

Fig 473 —Dangers of short circuiting when the ileo cæcal valve is competent In A, the cæcum became distended with mucus and burst In B the lower end of the ileum became so tense that it ulcerated and perforated as shown in C (Re-drawn from *Brit Journ Surg* Oct 1916)

of ileo sigmoidostomy (end-to side unilateral complete exclusion) for colonic stasis In the majority of cases, soon after the operation, a mass forms in the right iliac fossa composed of the cæcum filled with inspissated fæces, and the discomfort sometimes makes a subsequent colectomy imperative

Again, suppose an *inoperable* colon obstruction, e g advanced cancer If the growth is in the cæcum or at the ileo-cæcal valve the operation of complete unilateral exclusion is sound, but if the growth is at the hepatic flexure a similar procedure is unsound, as with complete obstruction of the colon due to advancing growth the cæcum and stump of the ileum may become so distended with mucus that it may eventually give way (Fig 473, B)

The same is true of a splenic flexure growth when an ileo-sigmoidostomy is unsound as the right colon and transverse colon are undrained

Attempts have been made to overcome this difficulty by anastomosis

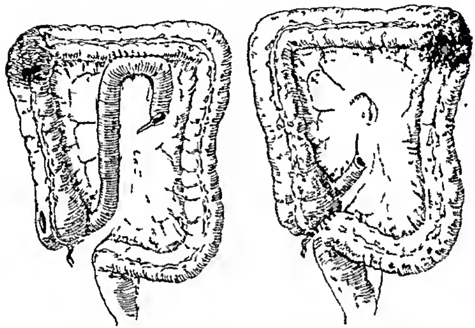

Fig 474 —Methods of short-circuiting devised to guard against the complications illustrated in Fig 473.

(Re-drawn from *Brit J ann Surg.*, Oct. 1916.)

between the cæcum and iliac colon (Giordano-Bergmann), but this leaves two long culs-de sac which again is essentially unsound

It seems quite clear that if it is impossible to avoid the formation of a cul-de-sac it should be drained by a fistula made at its extremity This is automatically ensured in the case of a fæcal fistula which acts as a vent for the small quantity of fluid excreted by the mucosa of the excluded intestine In other cases a deliberate independent small cæcostomy must be made *

Another danger arises in connection with lateral anastomosis even if resection is carried out Should the proximal blind end be too long

* Grey Turner *Brit Journ Surg* Oct 1916 p 277

there is a tendency for it to become permanently filled and to enlarge and become inflamed and ulcerated, and cases have been recorded where this end has given way and caused peritonitis Unfortunately the intestinal contents pass to the end of the proximal cul de-sac and overflow through the stoma afterwards so that this tendency of the proximal cul de sac to "balloon" is understandable The late Mr Carson used to quote the case of a patient, suffering from fæcal fistula after gangrenous appendicitis for whom he did bilateral complete exclusion (ileo transverse colostomy side to side), with subsequent removal of the excluded colon Two years and three months after the ileo transverse colostomy the woman fell downstairs and was immediately seized with generalized abdominal pain The abdomen was opened, and it was found that the proximal cul de sac had ruptured with considerable extravasation

When ileo transverse colostomy has been made as a first step in a two stage removal of the right half of the colon, blind ends may be avoided by making an end-to end anastomosis at the time of the excision (Dorling) Of course this can only be done when there is a sufficiency of bowel to admit easy approximation of the remaining ends after a sufficiently wide resection When these conditions obtain, this end to end anastomosis is a convenient method of completing the operation, and is easier and safer than tucking in two blind ends

CHAPTER XXI

OPERATIONS FOR CANCER AND OTHER CONDITIONS OF THE LARGE INTESTINE

By G GREY TURNER

EXCLUDING malignant disease of the rectum which comprises nearly half the cases of large intestine cancer and is considered under a separate heading any part of the colon may be affected though a very high percentage occurs in the left iliac and pelvic portions Thus in a series of 142 consecutive cases cancer occurred in the following situations —

Pelvic and iliac colon	69 times or	48 6%
Descending colon	9	6 8%
Splenic flexure	15	10 5%
Transverse colon	14	9 9%
Ascending colon and hepatic flexure	13	9 1%
Cæcum	22	15 5%

Types of growth —The majority of colon growths are columnar celled carcinomata There is comparatively little tendency to lymphatic spread and distant metastases are unusual It is for this reason perhaps that so much success attends Mikulicz s staged operation and Paul s method which as far as the removal of the actual diseased area and the adjoining lymphatics is concerned is very incomplete compared with the extensive operation planned for the extirpation of cancer in other situations But it is a great mistake to assume that all cases are of the same low degree of malignancy Some probably a third of the total number disseminate widely and it may be before the primary bowel growth has produced marked symptoms

Growths at the splenic flexure show less lymphatic involvement than cæcal or ascending colon growths and are generally of the scirrhous type Growths of the cæcum and ascending colon are more often of the massive ulcerating type and rarely give rise to obstruction Scirrhous growths are much more common in the left than in the right colon and so obscure are the symptoms in the early stage that it is estimated that in 40–60 per cent obstruction is the first sign of the disease It is this factor that is usually blamed for the high operative mortality and the decision as to the scope of the operative treatment primarily depends on whether obstruction is or is not present

The gross anatomical features of these growths are as important as their microscopic structure Four definite varieties may be recognized the massive growth forming a tubular stricture the infiltrating ulcer limited to a segment of the wall of the bowel the constricting type or ring carcinoma and the cauliflower or papillomatous variety The massive type is the most common up to the splenic flexure and

beyond that the constricting variety The papillomatous type is not so common as in the rectum and is usually only found in the lower part of the great bowel The recognition of the gross anatomical structure of bowel growths has already proved to be valuable in assessing the prognosis of those in the rectum (Cuthbert Dukes) The papillomatous variety is the least malignant whereas the ulcerative type which from the first exhibits infiltrating properties invading the bowel wall deeply is the most malignant In the former variety glandular involvement is infrequent and late whereas in the latter it is not only early but apt to be widespread When the growth is on the mesenteric side of the bowel the prognosis is unfavourable But these distinctions have more to do with prognosis than with treatment and do not in any way alter the general truth that growths of the large bowel are

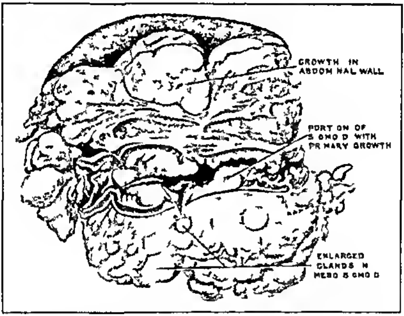

Fig 475—Carcinoma of the sigmoid involving a large area of the abdominal wall Excision with end to end anastomosis. The patient was alive and free from recurrence twelve years later

(By permission of The Lancet)

not usually particularly malignant and despite extensive local involvement they yield very good results when thoroughly removed The surgeon must therefore not be easily deterred and unless there is evidence of distant dissemination or of deposits in the peritoneum there are few cases in which the radical operation cannot be carried out with fair prospect of ultimate success But such an operation may have to be very extensive as for instance when the growth directly involves neighbouring structures There are many successful cases on record where growths invading the abdominal wall or the viscera e g the pelvic contents in women adjoining loops of small intestine or part of the stomach the spleen or the kidney or a portion of the liver,

have been successfully removed not only with immediate recovery but with freedom from recurrence for several years (Figs 475, 488) In dealing with malignant disease of the large bowel there can be no doubt that the thorough local removal is more important than any extension to remove the whole area of lymphatic drainage Fortunately, in many parts of the large bowel it is anatomically possible and comparatively easy to carry out an ideal operation for malignant disease, and this is particularly so with the right half of the colon Many of the glands found enlarged in these cases are not infiltrated with growth, but are inflammatory, the result of absorption from ulcerated surfaces While this forms no excuse for leaving glands that are obviously enlarged, it is nevertheless an encouraging feature The amount of healthy bowel to be removed on either side of the growth is a matter of great importance The spread of bowel cancer does not appear to be by submucous lymphatic permeation, and while it is desirable to remove a sufficient area, it must not be supposed that this necessarily means an extravagant resection in every case Probably 4–5 in above and 2–3 in below is a sufficient margin of safety in the great majority of cases

Surgical anatomy. Arterial supply. (Fig 476)—The colon is supplied by the superior and inferior mesenteric arteries through the following branches

From the superior mesenteric—By the *ileo colic*, which supplies the last 7 or 8 in of the ileum, the cæcum, appendix, and part of the ascending colon, anastomosing above with the vasa intestina tenuis and below with the right colic

By the *right colic*, which supplies the ascending colon, anastomosing above with the ileo-colic, below with the middle colic

By the *middle colic*, which supplies the transverse colon, anastomosing at the hepatic flexure with the right colic and at the splenic flexure with the left colic

From the inferior mesenteric—By the *left colic*, which supplies the descending colon, anastomosing at the splenic flexure with the middle colic, and below with the ascending branch of the sigmoid artery.

By the *sigmoid arteries*, which supply the iliac and pelvic colon, anastomosing above with the descending branch of the left colic and below with the superior hæmorrhoidal The anastomosis with the superior hæmorrhoidal is very variable, and this has been called by Sudek the ' critical point ' De Dietrichs, quoted by Hartmann,* says that if the inferior mesenteric is ligatured above the last sigmoid branch, circulation is maintained, but if below the last sigmoid branch gangrene of the rectum follows Pauchet (*loc cit*) says that if the inferior sigmoid artery and the superior hæmorrhoidal are tied separately, the circulation in the marginal artery (a term he applies to the anastomosis by arcades) is destroyed, and gangrene results *If, on* the contrary, the ligature is applied to the trunk of the inferior mesen-

* *Ann Surg.*, 1909 i, 1091

teric at a point below the last sigmoid artery, circulation will be maintained even in the superior hæmorrhoidal artery If, he adds, the marginal artery is preserved the middle colic artery can nourish the descending colon and sigmoid, even if the inferior mesenteric artery is tied at its origin Hamilton Drummond† investigated the blood supply of the descending colon and rectum He found that on pump-

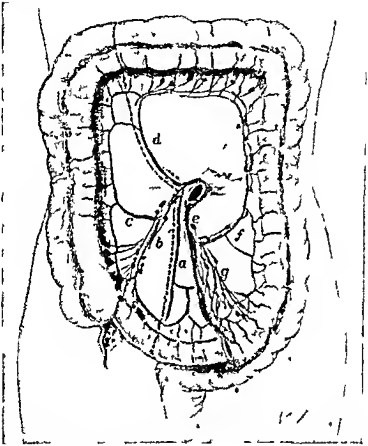

Fig 476 —Diagram of blood vessels and lymphatic glands of colon, with shaded area to show part removed in growths of right colon.

a Superior mesenteric artery *b* ileo colic artery *c* right colic artery *d* middle colic artery *e* inferior mesenteric artery *f* left colic artery *g* sigmoid branches

ing barium sulphate and almond oil into the inferior mesenteric artery, it was possible to inject the branches of the superior mesenteric if the ileo colic branch was not tied, and if the superior mesenteric was ligatured at its origin, it was possible to inject through the inferior mesenteric all the vessels of the large and small intestine up to the duodenum He came to the conclusion that if the stump of the bowel is to be brought down after high excision of the rectum, the inferior mesenteric artery should only be ligatured below the first sigmoid branch

If the recto sigmoidal loop is small gangrene may result from tension,

† *B r Journ Surg* April, 1914 i 677

and it is better to do a permanent colostomy in which case it is safe to ligature the inferior mesenteric artery immediately below the point where the left colic artery is given off In actual practice the surgeon should determine by direct inspection and palpation whether or not the blood supply is adequate at the point at which anastomosis is to be made

Lymphatic distribution —Our knowledge of the lymphatic vessels and glands draining the colon is due to the researches of Jamieson and Dobson * They describe four groups of glands—(1) the *epicolic* on the intestinal wall (2) the *paracolic* on the arterial arcades (3) the *intermediate* along the main arterial supply and (4) the *main group* round the arteries at their origin In a series of diagrams they represent the scope of an operation necessary to remove a colonic growth in various situations with its lymphatic area bearing in mind the arterial distribution Thus for growths of *cæcum and ascending colon* the ileo colic branch of the superior mesenteric artery must be tied at its origin and all the intestine supplied by it removed with its mesentery and lymphatic distribution This involves removal of the last 6 in or so of the ileum the cæcum ascending colon and hepatic flexure

For growths of the *hepatic flexure* the parts supplied by the middle colic artery must be removed and as this devitalizes a large part of the ascending colon especially when the right colic artery arises from the middle colic the upper section should be through the ileum at the same point as for cæcum and ascending-colon growths

For *transverse colon* growths only the paracolic glands need be removed with the colon which must be resected 3–4 in on each side of the growth

For growths of the *splenic flexure* all the bowel supplied by the left colic artery and its associated lymphatic area must be removed i e the colon from the junction of the middle and left third of the transverse colon to the middle of the descending colon

For growths in the *descending colon* the same point is taken on the transverse colon while below the colon is divided at the middle of the sigmoid flexure supplied by the upper sigmoid artery

For growths in the *sigmoid flexure* the point of origin of the left colic artery is the limit for lymphatic removal

These are of course ideal resections and it may be well to remember that growths of the left colon tend to the scirrhous type with comparatively limited lymphatic involvement

EXCISION OF GROWTH

Excision of a malignant growth is the operation most often required in the surgery of the large bowel Since the earlier stages of its development half a century ago a great many different methods have been evolved Most of these concern matters of detail but some involve

* *Ann. Surg* 1909 *I* 1077

important principles At the present time it is generally agreed that no attempt at excision should be made in the presence of obstruction, which must first be dealt with by drainage of the bowel In the absence of obstruction or when this has been successfully overcome the methods available are —

(1) Intra-peritoneal excision, with immediate restoration of continuity by direct anastomosis
(2) Preliminary drainage of the bowel by cæcostomy or colostomy, followed after an interval of two or three weeks by intra-peritoneal excision and restoration of continuity by anastomosis As a last step, a further operation for the closure of the colostomy is usually required This is the typical many stage operation
(3) Preliminary defunction of the portion of bowel containing the growth This is brought about by making a colostomy with the two ends so far separated that there is not likely to be contamination from one to the other In this way the loop containing the growth is completely isolated and can be treated by irrigations etc, with the object of reducing its infectivity to a minimum After a time the growth is resected and continuity restored As a final stage the colostomy is repaired This is the method of Sir Hugh Devine
(4) With or without preliminary bowel drainage, the portion of bowel containing the growth is mobilised and brought outside the abdomen, and is then excised The bowel ends are stitched side by side so that they resemble a double barrelled gun, and are then fixed in the wound Continuity is later restored by destroying the spur, though sometimes a further intervention is necessary to complete the closure This is the method known by the name of Paul of this country and Mickulicz of Germany

Many modifications have been introduced in each of these methods

Whatever method is used, excision of the colon is attended with much greater risk than the similar procedure in the small bowel The principal reasons are as follows —the blood supply is not so generous, the appendices epiploicæ interfere somewhat with the suturing, the contents of the bowel are more infective and this is often *heightened* by obstruction A further reason is the opening up of the extra-peritoneal cellular tissue which is often a necessary accompaniment of the intervention

General Considerations

The frequent association of obstruction with colonic growths influences their management so much that it will be easier to consider the operative treatment under two heads—(1) in the absence of obstruction, and (2) when obstruction is present It is accepted generally that in the presence of obstruction the duty of the surgeon is to relieve

it and do nothing more at a first intervention No operation for the radical removal is *justifiable* in the presence of obstruction In my practice the operation in two stages exactly halved the mortality

If the abdomen is distended and tense and the patient is vomiting it is certainly unwise to carry out any exploration In these circumstances a blind cæcostomy provides the maximum advantage But it must be borne in mind that this operation cannot do more than relieve the distention of the bowel proximal to the growth and provide *for the escape of intestinal contents* It does not ensure that the bowel will be completely emptied or that it will recover its normal size and condition If the growth is some distance away from the cæcum it will be necessary to prepare the bowel by careful and repeated irrigation before any further operation otherwise it will be found to be distended thickened and œdematous while it may also be ulcerated If the obstruction is of a lesser degree and the abdomen is only slightly distended or merely full while *at the same time the condition of the* patient will not allow the necessary careful examination by opaque enema etc it may be feasible to open the abdomen in the middle line for the purpose of exploration

Exploration—This can seldom be adequate through an incision which will merely admit the greased hand as is sometimes advised The object of the exploration is to determine the presence or otherwise of secondary deposits in the liver the condition of the lymph nodes and whether there are such extensions of the growth to neighbouring parts as to render an attempt at removal inadvisable

The examination of the liver can be conducted blindly but the relation of the growth to the surrounding parts can only be determined accurately under the guidance of the eye If the surgeon has no hint of the location of the neoplasm the incision should be in the mid line below the umbilicus The presence of a growth having been verified the liver should next be examined If palpation of the edge or the under surface gives definite information of secondary deposits the upper surface should not be explored because passage of a hand between the liver and the diaphragm certainly increases the risk of pulmonary complications Angiomata adenomata and calcified scars and in some parts of the world small hydatids may all simulate secondary deposits of new growth A multiplicity of nodules of not less than half an inch in diameter with umbilicated depressions about their centres is characteristic of metastatic growths

If deposits are found the question arises whether anything radical should be done In the presence of multiple nodules nothing but steps to correct or to anticipate obstruction by a lateral anastomosis or by colostomy are justifiable To determine the significance of enlargement of the lymph nodes and the degree of local extension it may be necessary to enlarge *the incision to use retractors* and often to employ the Trendelenburg posture It may be very difficult to decide whether the condition is neoplastic or inflammatory Sometimes a lymph node may be easily removed for microscopic examination but unless this

yields a positive report of malignancy, it may be deceptive, for very often malignant lesions are associated with enlarged nodes which are only inflammatory It is not wise to attempt to remove a piece of the mass in the bowel for biopsy because the little wound may not heal and peritonitis may result Nodules of growth on the peritoneum are of much worse prognostic significance than quite extensive direct involvement of viscera, parts of which can be removed with the growth But whatever the condition found, at the back of the surgeon s mind should always be the admonition not to be easily deterred

This exploration may be followed either by a colostomy at the most convenient spot in relation to the growth or by a preliminary anastomosis The abdomen ought then to be closed and, with the certain knowledge which such an exploration has furnished subsequent interference for removal of the growth can be carried out with great precision

Where there is no question of an acute or subacute obstruction the operation may be carried out in one stage In these circumstances the surgeon must use his own judgment whether a temporary cæcostomy should be made as a last step in the operation to provide against distension of the bowel following the interference If there has been recent obstruction, or if the proximal bowel is at all distended or if it contains much fæces, or if the operator has any reason to doubt the accuracy of the anastomosis, then it is much wiser to make a small cæcostomy which may close spontaneously after it has served its purpose But it must be emphasized that this type of cæcostomy is never so satisfactory as one made as a deliberate preliminary a week or two previously It always takes a few days for bowel drainage to become well established and until that takes place the advantage of the cæcostomy is doubtful Fatal cellulitis of the abdominal wall, originating at the site of a cæcostomy made at the end of a long operation, has marred an otherwise satisfactory resection If the resection is in the sigmoid it is also important to leave a tube in the rectum to guard against distension with flatus and to allow the escape of fæcal débris and mucus In most cases it is wise to bring a softened rubber tube or a tissue drain from the neighbourhood of the anastomosis to the surface through the most dependent part of the parietal incision

Preparation.—In cases where obstruction is absent or has been relieved by drainage, there is time for adequate preparation before undertaking removal of the growth The most important points are emptying the bowel below the growth by moderate enemata and irrigation with saline solutions Where there is no opening into the bowel above the growth, enemata must be used cautiously, for it may be easier for a copious injection to find its way through the growth into the bowel above than to return safely, and sometimes an attack of obstruction has been precipitated in this way When there is no obstruction, mild aperients such as confection of sulphur and senna and liquid paraffin are valuable For twelve hours before operation the bowel should be rested, all medicines and irrigations being discontinued

and 10 min of tinctura opii given twice during this time It is also important to prepare the whole intestinal canal by careful selection and limitation of diet In principle those foods which are known to leave a considerable residue or to cause gaseous distension should be avoided At the same time the patient must have a sufficient diet such as may be made up from soups eggs arrowroot or ground rice with cream sugar fruit juices and dry biscuits and plenty of harmless liquid During this probationary period the patient should not necessarily be confined to bed The principle is to attain the maximum of healthy resistance with the least abdominal distension and this may be promoted by moderate exercise Stimulants and tobacco must be strictly limited Anæmic patients should be treated and if anæmia is well marked a preliminary blood transfusion is invaluable.

There is no one intestinal antiseptic which can be relied upon to sterilize the contents of the bowel at all events in any time that could be reasonably spared for preparation and therefore delay for this purpose is not justifiable It is well to give liquid paraffin for a few days before operation and this may be helpful in convalescence Attempts have been made to raise the resistance of the peritoneum to infection by substances which increase leucocytosis and by the administration of vaccines and much reliance is placed on these steps by some surgeons In two-stage operations the preparation is carried out before the resection especial care being taken to cleanse the bowel below the colostomy by repeated irrigations

Technique—The most important points are to secure adequate exposure by suitably placed incisions and to effect thorough mobilization so as to ensure complete removal and to enable union to be made without tension Whenever the growth is fixed by adhesions or by invasion of the surrounding structures the incision should be made directly over it or if a median or paramedian incision has been made the surgeon should not hesitate to make a separate independent incision over the growth or to add a transverse incision to his original one (Fig 477)

The proper mobilization of these growths converts many a hopeless looking case into a promising one but it must be done under direct vision and for this reason *the exposure by incisions directly over the* affected area is very valuable

When the fixity is due to peritoneal adhesions they are often an exaggeration of those bands and membranes which are so common in connection with the large bowel These can always be dealt with by free use of the scissors but there is often a good deal of bleeding which must not be neglected If on the other hand the fixation is due to actual infiltration of surrounding parts by the growth the problem of its removal can only be settled under the guidance of the eye In the absence of distant dissemination the surgeon must not be easily deterred * and there is no excuse for timidity

The technique of the anastomosis is dealt with in the previous

* See Medical Society Oration on Cancer of Colon, Grey Turner *Lancet* May 18 and 25 1929 i, 1017 and 1073

section but of course it admits of much variation in detail The essentials for success are to ensure that the parts have an adequate blood supply that they can be made to lie in apposition without tension and that the edges to be sutured are not damaged by crushing clamp or cautery Every anastomosis of the large bowel should be protected by neighbouring appendices or omentum or loose tissue tacked over the outer suture line Whenever there is the least doubt

A

B C

Fig 477—A shows the incisions employed for the removal of an adherent growth of the splenic flexure To enable mobilization to be carried out the cross cut through the rectus had to be employed The patient was operated upon by Paul s method and was alive and well ten years afterwards B shows the incision used for the removal of an adherent growth of the ascending colon with many glands The bowel from the lower ileum to the middle of the transverse colon was excised C shows a similar incision employed for an adherent growth of the descending colon. An exploration was previously carried out through the median incision

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of the integrity of the suture line a drain should be brought from its neighbourhood to the surface

Extra-abdominal resection—There are some special methods of resection applicable to the large intestine which are favoured by many surgeons Of these the methods of Paul (1895) and Mikulicz (1902) are similar in principle They both recognize the value of conducting the resection in stages and the importance of intestinal drainage Paul s method is the more frequently employed If the growth has not previously been located an exploration through a

median incision is the first step Otherwise an incision is made directly over the growth which is mobilized under the guidance of the eye and the vessels in the corresponding part of the mesentery are ligatured and divided the loop containing the growth is thus isolated and brought outside the abdomen The two limbs are then lightly sutured together for about 4 in above the point at which it is considered wise to make the division of the bowel so that they look like the barrels of a gun the growth is then cut away and Paul s glass tubes are tied into either end As a last stage the abdominal wall is drawn together around the ends of the bowel one or two stitches being required to fix the intestine securely to the skin In about ten days the glass tubes loosen during this time the upper intestine discharges more or less freely depending on the degree of obstruction which has been present

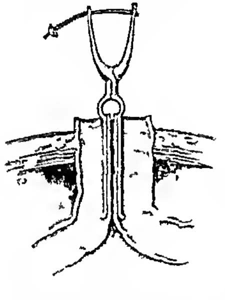


Fig 478 —Spur between the loops of intestine clamped with an enterotome.

After the tubes have come away the ends of the intestine gradually retract and the wound soon cleans up About two weeks after the operation if the patient is in good condition the spur between the two loops is clamped with an enterotome before which the septum gives way leaving a free opening between the loops (Fig 478) The enterotome is not intended to divide the spur but to bring about its destruction by pressure necrosis For this purpose it should be gradually tightened twice a day until it loosens The external fistula then begins to contract and may even heal spontaneously or it may have to *be closed by a further plastic operation making the third* stage The whole proceeding takes two or three months The results both immediate and remote are good but to enable the bowel to be brought outside the resection has often to be more limited than is desirable It is perhaps in consequence of this limitation that recurrence in the scar of the abdominal wall is not uncommon

When there has been a delay of a fortnight or more in applying the enterotome the septum may be hard and rigid In these circumstances it may be difficult to get the instrument to grasp the septum and stay in position and some other method will be required That part of the septum nearest the open end of the bowel may be destroyed with the cautery or the bowel may be loosened from the parietes to assist its retraction By either of these means the channel may be

gradually restored, leaving the external fistula to be closed by a plastic intervention

There are many modifications of this plan, such as making a lateral anastomosis at the first operation, the ends of the bowel being clamped and divided flush with the surface of the abdominal wall When the anastomosis begins to function, the bowel retracts into the abdomen and the external fistula contracts and may even close spontaneously, though it usually requires some local interference to complete the process It may be that it is the retraction of the bowel which encourages the anastomosis to function, and this can be aided by the regular use of small enemata to secure emptying of the rectum Yet another plan is to remove the growth, make a lateral anastomosis, and then close the bowel ends, leaving them anchored to the parietes just beneath the skin, so that if anything goes wrong a fæcal fistula can readily form This often closes spontaneously

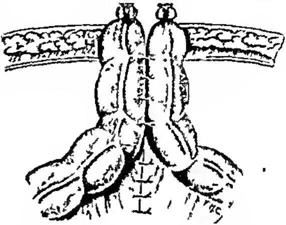


Fig 479 —Obstructive resection The limbs of the colon are sutured together and the ends are in the grasp of crushing clamps flush with the abdominal skin surface

In **obstructive resection** (Fig 479) the limbs of the loop are sutured together and are clamped at the skin level The clamps are kept in position for three or four days, until the parts are safely sealed off and are then removed when there is no risk of a spreading infection After about a week, the enterotome can be applied as in the original method

Any of these methods may be employed after preliminary bowel drainage by cæcostomy or colostomy

Even in cases where the growth can be easily mobilized, many *surgeons are in favour of the many-stage or Paul operation This is* especially indicated in growths of the colon between the hepatic flexure and terminal sigmoid, a region in which 70 per cent. of cases of cancer of the large intestine are situated

The advocates of the many-stage operation point to the fact that immediate restoration of continuity in this region is made dangerous by the solid nature and high infectivity of the intestinal contents, by defective peritoneal covering, and by the difficulty of serous approximation owing to fat-deposit Many patients are debilitated, and leakage and septic complications are not infrequent

Defunctioning colostomy.—It was in an endeavour to diminish these risks that Sir Hugh Devine introduced the method known as

the defunctioning or disconnecting colostomy * In cæcostomy, and to a lesser extent in ordinary colostomy, some of the fæcal contents find their way into the distal portion of the bowel which, in consequence, remains contaminated and does not enjoy complete physiological rest To overcome these defects Devine devised a type of colostomy in which the two openings were so far separated from each other and were so small that the risk of contamination from one to the other was practically eliminated Further, by treatment of the isolated distal loop he attempted to bring about "debacterialization" of the involved segment

Technique —In dealing with growths situated beyond the middle of the transverse colon the peritoneal cavity is opened by a vertical incision through the upper part of the right rectus, about 2½ in long A loop of transverse colon 4 or 5 in long is withdrawn and the limbs are sutured together, leaving a gap near the summit The parietal peritoneum is then stitched all round the neck of the loop Button-hole openings are made through the skin and subcutaneous tissue 1 in to the side of the vertical incision Strong clamps are passed through these button-holes to emerge through the original incision where they are applied to each side of the summit of the prepared loop, which is then divided with the cautery between the clamps By means of its clamp each portion of bowel is then withdrawn through its corresponding button-hole, the clamps being left *in situ* on the surface of the abdominal wall The rectus incision is then closed The clamps are not removed until the bowel is securely united in its new position, which will usually be in about a week Devine lays stress on the necessity of small openings, and to attain this end he purposely makes the button hole small and bunches up the bowel in the grasp of the clamp After the colostomy is established it is usual to allow about three weeks for the cleansing and "debacterialization" of the distal loop For this purpose most reliance is placed on repeated irrigations with saline, but antiseptic wash-outs or any other effective means may be employed When it is judged that the opportune time for the removal of the growth has arrived, this may be carried out either by the intra- or extra-abdominal method, but, because of the thorough cleansing of the affected bowel which is possible, Devine now considers that the intra-peritoneal methods are largely robbed of their risk

The final operation for destroying the colostomy spur and thus establishing function is done by a special enterotome When continuity is established, the colostomy openings retract and become very small, though it may require one or more applications of the cautery to promote final healing In non malignant conditions much longer time should be allowed between the establishment of the colostomy and the resection Many modifications have been suggested but only in detail

* Brit Med Journ, Dec 28, 1935 ii 1245

Where immediate drainage of the bowel is necessary a cæcostomy is carried out a couple of weeks before making the defunctioning colostomy

General after-treatment.—With a drainage cæcostomy, this is very simple At the end of three or four days the tube is removed from the rectum, and, if there has been no evacuation by the end of a week, a glycerin enema may be given This may bring away a small stool which has accumulated in the bowel After that, flatus may be passed occasionally or the patient may even have the bowel moved naturally In any event it is not wise to close the cæcostomy until at least three weeks after the resection, and if the latter has been difficult or there has been some subsequent trouble, say from infection, it is better to wait a week or two longer To close the cæcostomy too early is to risk a fistula developing through the wound used for the resection Where there has been no preliminary drainage of the large bowel the rectal tube is invaluable and should be left *in situ* for a week, a little oil being run into the rectum every second day As soon as the patient is able to take it, liquid paraffin should be given by the mouth If at the end of a week there has been no bowel action, a glycerin enema may be administered and may be repeated every second day if required Generally speaking, it is unwise to use any laxative sooner than a fortnight after the operation During the first 48 hours only small amounts of fluid nourishment, principally glucose solutions, are given by the mouth Subcutaneous or intravenous glucose must be used if resistance is poor, some surgeons make it a routine In the surgery of the large bowel it is not safe to use rectal alimentation A similar diet to that used during the preparatory period is best for the first week If during the first two or three days the patient is troubled with windy distension, this must be relieved by limiting the intake and by such other measures as are used in any abdominal case, but it must be remembered that after resection of the large bowel large enemata cannot be safely employed Glycerin enemata or suppositories are very useful and will usually bring relief

Non Obstructed Cases

These can be subdivided into two groups—(1) those in which a radical operation can be attempted, and (2) those in which, because of visceral or peritoneal metastases, such an operation is inadvisable or impossible

(1) When a radical operation is possible.—The radical operation consists in adequate removal of the diseased segment together with its corresponding lymphatic area, preservation of the blood supply of the parts left behind, and restoration of the continuity of the intestinal canal The type of operation depends on the arterial supply and the extent of the serous covering The distribution of the arterial supply and its relation with the lymphatics varies so much in different parts of the colon that the extent of the resection required differs consider-

ably Thus in cancer of the *cæcum, ascending colon or hepatic flexure* it is necessary in order to make a safe lymphatic clearance, to remove all that part of the intestine which is supplied by the ileo colic branch of the superior mesenteric artery As the right colic is often given off from the ileo colic artery the part resected must be that contained between the lowest part supplied by the last ileal branches of the superior mesenteric and the highest part supplied by the middle colic amounting to the last 6 in of the ileum the cæcum ascending colon,

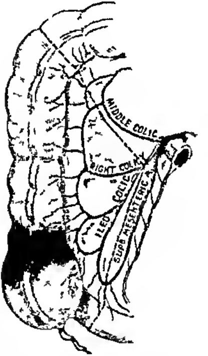


Fig 480 a —Diagram showing parts resected in growths of ileo cæcal valve cæcum and ascending colon.

The division of the large bowel is usually made in the transverse colon beyond the hepatic flexure

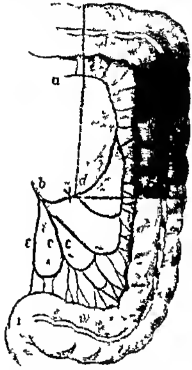


Fig 480 b —Diagram of splenic flexure resection

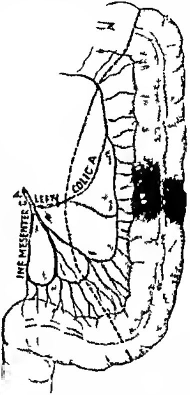
a Middle colic artery, b inferior mesenteric artery c sigmoid branches d left colic artery

hepatic flexure and a portion of the right half of the transverse colon (Figs 480 to 485) Restoration of continuity by means of an end to-end or an ileo transverse anastomosis is comparatively safe and easy The ileum can usually be readily united to the divided colon end to-end, but if there is great disparity the ileum may be cut across obliquely or the end of the colon may be diminished by suture (Fig 472)

In cancer of the *transverse colon* resection, with removal of the paracolic glands and end to end anastomosis is recommended and generally speaking the same course is to be followed in cancer of the *iliac colon* where there is a complete serous covering (Fig 482)

In cancer of the *splenic flexure and descending colon* a wide resection is necessary to ensure a good blood supply to the anastomotic ends (Figs 480b and 481) and owing to the absence of a complete serous coat in the descending colon the aim if direct union is to be attempted must be an anastomosis between the iliac and transverse colon after complete mobilization The restoration of continuity in these cases can usually be done by the end to end method but it may be difficult If it is impossible it will be necessary after resection of the growth and closure of both ends to anastomose either the cæcum or the ileum to the sigmoid by the lateral method *

Generally speaking the arterial branches supplying the colon are of considerable size and capable of carrying on the nutrition of the bowel for quite a distance from their source But this can only be determined by actually seeing or feeling the vessels pulsating or inspecting the bleeding ends of the bowel after temporary removal of the clamps In these circumstances it is safe to make a direct anastomosis though it is always wise to bring a drain from the region of the union to the surface



F g 481 —D agram showing parts *resected in growths of descend ng colon*

A more limited resection of the descending colon than that shown in Fig 481 may be adequate so far as removal of the growth is concerned but the restoration of the bowel depends first on the blood supply and second on approximation without tension and these conditions can usually be best subserved by the wide removal of bowel

In cancer of the *pelvic colon* (Fig 483) there are three alternatives—(1) excision of the diseased area with end to end anastomosis direct or by invagination (2) excision of the diseased area *with permanent* colostomy and closure of the lower end and (3) permanent colostomy with removal of the pelvic colon and rectum (abdomino perineal excision)

(2) **When a radical operation is impossible** —In this group where for one reason or another the growth cannot be removed the object is limited to the prevention of obstruction This may be attained by a short circuit which is the ideal plan or by permanent external drainage by colostomy according to the situation of the growth

Cases where Obstruction is Present

Operations in the presence of obstruction are always difficult and attended with a high mortality rate It may be taken as a general rule that a great deal will be gained if it is possible to relieve the obstruction before operation It is well known that obstruction of the large gut especially of the left colon and rectum may exist for long periods without causing acute symptoms It is also recognized that in some cases the exciting cause of the stoppage is the impaction of hardened fæcal masses food particles or foreign bodies in the constricted portion of the intestine In obstruction due to stricture

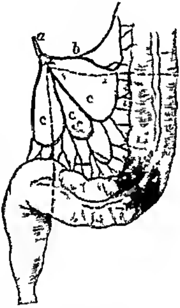


Fig 482 —Diagram showing parts resected in growths of iliac colon

a Inferior mesenteric artery *b* left colic artery *c* sigmoid branches

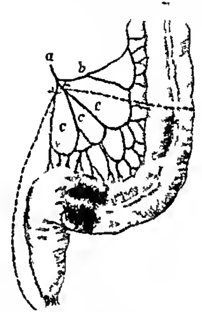


Fig 483 —Diagram showing parts resected in growths of pelvic colon. The shaded parts are those removed in abdomino perineal resection of the rectum.

(For references, see previous figure)

at the lower end of the left colon an attempt may be made by limiting food by the mouth by the administration of nux vomica with salines and by repeated enemata to overcome the obstruction before operating This treatment cannot be continued for more than a short period even in definitely chronic cases as the patient who is probably debilitated cannot maintain strength without nourishment and because—and this is very important—in these long standing cases there is a tendency to perforation of stercoral ulcers either immediately above the stricture *or in the cæcum* When signs of acute obstruction have been superadded to the chronic the time for palliative treatment has passed When in doubt a preliminary cæcostomy is the only safe rule

It is a cardinal rule that *in cases of obstruction it is unjustifiable to attempt a radical cure in one stage* i e resection of the affected area

and restoration of continuity All the evidence goes to prove that this procedure is attended by a prohibitive mortality, and the practice is now universally abandoned The first step is to relieve the obstruction, and no more should be done at this stage

The method adopted must vary with the position of the growth and the possibility of eventually doing a radical cure so that here also there will be two groups—(1) where obstruction is present with an operable growth, (2) where obstruction is present with an inoperable growth

(1) Obstruction with operable growth.—The object in view is to relieve the obstruction, and on a subsequent occasion to perform a radical operation, i e removal of the growth with the affected lymphatics, and restoration of the continuity of the intestinal canal In this group the many-stage operation is particularly indicated

When the obstructive symptoms are marked and the abdomen is distended, blind cæcostomy is the method of choice and presents most advantages to the patient

When the symptoms are milder and the abdomen is not distended, the procedure recommended is a midline subumbilical incision long enough to admit the hand, exploration to determine the site of the growth and the prospects of a radical cure and, if this is favourable, closure of the wound and the formation of a cæcostomy through a separate opening This applies to colonic obstruction at or beyond the hepatic flexure In cases of obstruction at or near the *ileo cæcal* valve, and in the rare cases of obstruction due to a growth of the ascending colon, a *short-circuit (ileo-transverse colostomy)* is the preliminary operation of choice, and is preferable to an enterostomy *in the small intestine*

(2) Obstruction with inoperable growth.—The ideal in these cases is to relieve the obstruction, and by such means as shall prevent its recurrence This may be achieved by a short-circuit or an artificial anus, and though the surgeon may aim at the former, circumstances may force him to adopt the latter The deciding factor is usually the site of the growth In the majority of cases (75 per cent) the *growth is either in the rectum or the pelvic colon, and in that situation* a short-circuit is usually impossible, and an artificial anus has to be chosen

If the growth is in the cæcum or at the ileo-cæcal valve, the operation of choice is an ileo colostomy either to the ascending colon or to the first part of the transverse colon When the obstructing growth is at or near the hepatic flexure, the cæcum can sometimes be united to the transverse colon or sigmoid This must never be attempted unless the parts can be approximated without tension

The attempt to short-circuit an obstructive growth in the transverse colon or splenic flexure introduces the objectionable feature of the cul-de-sac, and for this reason an ileo-sigmoidostomy should be avoided whenever possible A colo colostomy is quite satisfactory, but it must

not be made too near to the growth as there is a tendency for the anastomotic opening to be invaded If this anastomosis cannot be made, the surgeon must decide between (1) a permanent artificial anus proximal to the obstruction, and (2) complete unilateral exclusion, by division of the ileum near the ileo cæcal valve, and ileo sigmoidostomy (side to side or end to side), with drainage of the excluded segment proximal to the obstruction (*see* p 930) Transverse colostomy is not quite such a satisfactory operation as in the iliac colon, but the opening can be well protected by a belt

Technique of radical operations in the different parts of the colon — Ileo-cæcal valve, cæcum, and ascending colon, including the hepatic flexure — Even when the question of obstruction does not arise many of these cases are best dealt with by a two stage method and this especially applies to those with very fixed growths those of large size or when the patient is in poor condition The first stage comprises exploration and ileo colostomy by the end to side or side-to-side method and the second removal of the growth and right half of the colon For the removal a vertical incision is usually employed either in the middle line below the umbilicus or through the right rectus An oblique or directly transverse approach (Fig 477, B) is very satisfactory and often essential with large fixed growths If the surgeon starts off with a vertical incision and finds himself embarrassed for want of access he should never hesitate to make a cross cut towards the loin The cæcum and ascending colon are mobilized by freely dividing the peritoneum as it passes from the colon to the parietes, and elevated towards the middle line by blunt dissection (Fig 484) During this step great care must be taken because the second part of the duodenum and the ureter are apt to be stripped up with the bowel Unless these structures are infiltrated by growth or involved in inflammatory exudate they can usually be easily separated once they have been identified In the rare cases where the duodenum is invaded by the growth a piece of the convexity may be safely cut away, the resulting defect in its wall being repaired in the transverse axis The fact that the duodenum is uncovered by peritoneum does not interfere with healing provided two layers of suture are carefully employed If the ureter is involved it may be possible to cut away a section and to restore continuity or the corresponding kidney may be excised, or the ends simply ligatured and allowed to retract into the cellular tissue Not infrequently the fascia covering the iliacus or even the muscle itself is invaded In these circumstances part of the muscle must be removed The surgeon must take care not to injure the anterior crural nerve at the outer border of the psoas or the iliac vessels at the inner border The process of mobilization is continued until the ileo colic artery is exposed at its origin from the superior mesenteric The cæcum and ascending colon, with the last part of the ileum can now be withdrawn from the abdomen and if the mesentery is not too much loaded with fat, the ileo-colic and middle

colic artery with its branches can be clearly seen The ileo colic artery and vein are tied as near their origin as possible and divided between ligatures A point on the ileum about 6 in from the ileo cæcal valve is chosen and an opening is made through the mesentery as near the intestine as possible The vessels are controlled by pressure forceps and the mesentery incised towards its attachment the anastomotic branches between the ileo colic artery and the terminal intestinal artery being secured The ileum is then held in two pairs of clamps and divided between them If it is intended to restore continuity by

Fig 484 —Resecting ascending colon first stage

The parietal peritoneum ... colon has been incised and the colon lifted from its bed by blunt dissection. The duodenum and kidney exposed

implanting the proximal end of the ileum into the transverse colon (end to-side) this end is left in the grasp of a clamp for the time wrapped up in a moistened gauze pad If it is intended to do a side to end (side of ileum to cut end of transverse colon) or a lateral anastomosis with the transverse colon the cut end of the ileum is closed by ligature or a running suture through all coats and is inverted and covered in by a purse string suture the end of which is left long as a convenient handle

A point is now chosen on the transverse colon preferably just beyond the hepatic flexure and in any case at least 8 in beyond the growth If this is within the attachment of the great omentum it should be cleared by stripping the omentum off the bowel by a scalpel close to its

attachment An incision is made through the mesentery and extended towards its attachment the anastomotic branches between the middle colic and the ileo colic and right colic arteries being secured before they are cut The colon is then clamped by two pairs of forceps at the point selected and is divided between them (Fig 485) If it is decided to restore continuity by implanting the ileum into the colon (end to side) or by lateral anastomosis the distal end of the divided

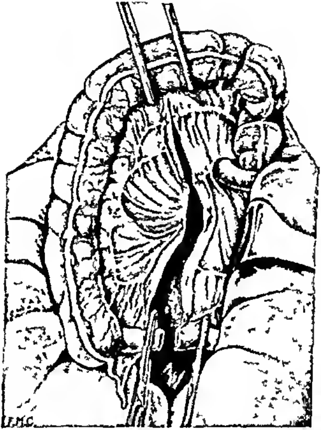


Fig 485—Resecting ascending colon second stage

colon is closed in the same manner as the ileum a step which is made much easier if the great omentum has been stripped from the colon as advised It is tempting to occlude the colon by an encircling ligature and to tuck in the end after applying a purse-string suture This plan may be easily accomplished in a thin attenuated bowel but otherwise may be difficult and unsatisfactory The portion of intestine to be removed is now isolated and is attached only by the remains of its mesentery This mesenteric attachment is very methodically mobilized the section of intestine being separated still farther towards the middle line by wiping the mesentery upwards and inwards from the posterior wall Great care must be taken not to injure the duodenum By this

means a very complete block-removal of the lymphatic area can be achieved The base of the mesentery is caught in sections by artery forceps and is divided between them, and the intestine with its mesentery removed *Continuity is now restored either (1) by end-to-end anastomosis*, which is strongly recommended it is often easy and satisfactory, the ileum being dilated enough to make it fit the end of the colon, but if there is marked disproportion it can be cut obliquely, or the side of the cut end of the colon may be diminished by suture (Fig 472) the union is made by direct suture with two layers of chromic catgut, (2) by implanting the ileum into the side of the transverse colon end to side anastomosis, or (3) by lateral anastomosis

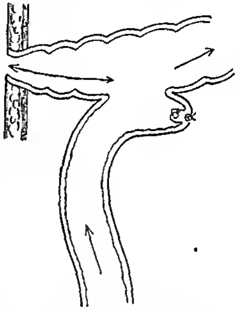


Fig 486 —Method of temporary bowel drainage after excision of the cæcum or right colon

The final stage consists in an endeavour to repair the peritoneal gap which has resulted from the separation of the resected segment from the posterior abdominal wall The free edge of the mesentery of the ileum may be united to the free edge of the transverse mesocolon, thus reducing the gap considerably, and it may even be found possible by careful suturing to cover in the remaining area If it is not feasible to cover the bare area completely, it should be reduced as much as practicable by drawing the peritoneum over the denuded structures as far as that can be accomplished without tension It is then fixed to the underlying parts by a stitch here and there to prevent its retraction In this region no harm will follow even if a considerable area has to be left uncovered When a portion of the iliacus muscle has been taken away the area must be packed with gauze There is often a good deal of oozing which cannot be easily arrested, and it is wise to leave in a softened drainage-tube or a tissue drain on top of the gauze

Temporary enterostomy in removal of cæcal growths—This may be a wise precaution where the operation has been carried out in one stage in the presence of some degree of obstruction, as shown by distension of the ileum with fluid contents, or when the surgeon for any reason is not very confident about the suturing A catheter may be placed in the ileum about a foot above the anastomosis, using the same technique as in jejunostomy Or the plan indicated in Fig 486 may be adopted If the first method is employed the catheter

may be removed at the end of a week or ten days when this type of enterostomy usually closes spontaneously In the other plan the fistula may heal naturally or it may have to be deliberately closed at the end of two or three weeks or sooner if the discharge is very liquid and troublesome

Transverse colon —This part of the bowel has a simple blood supply a lymphatic area which is but little invaded except in the vicinity of the growth and a long mesentery which allows free movement and easy approximation The only difficulty lies in the presence of the great omentum but the part corresponding to the bowel to be excised should be taken away with the growth The omentum by the side of the divided bowel should be separated from the colon by the Lardennois Pauchet method for a short distance as this facilitates the anastomosis At least 3 in of bowel on either side of the edge of the growth should be removed

An incision is made through the mesentery as near to the gut as possible at the point of section and extended towards the root of the mesocolon to include a V shaped area The mesentery is doubly caught in large artery forceps and is divided between them All bleeding points being secured the colon is doubly clamped at the agreed line of section and divided The same course is followed on the other side of the growth

The two clamps controlling the ends to be sutured are wrapped in moist gauze swabs and put aside for the moment

The segment to be resected is now held only by the gastro-colic omentum The great omentum is divided by vertical incisions extending from the point of section to its free edge on both sides and all bleeding controlled For this purpose strong artery forceps with good holding surfaces should be employed and ligatures should *be tied firmly and slowly to diminish the risk of retraction of the* blood vessels The gastro-colic omentum is then tied off by trans fixion close to the greater curvature of the stomach but preserving the gastro epiploic vessels The clamps holding the distal and proximal cut ends of the bowel are approximated and an end to-end axial anastomosis made The gap in the mesentery is closed and the operation completed by suturing or ligaturing together the two portions of what is left of the great omentum and gastro-colic omentum

Splenic flexure and descending colon —The resection of this portion of the colon is the most difficult of all Partial or complete intestinal obstruction is often present (in 60 per cent of cases) and resection can be undertaken only after the obstruction has been relieved by a preliminary operation The flexure is situated high up under the ribs in the left hypochondrium it rarely has a complete serous investment it is in close relation with the spleen and left kidney and is retained in position by a strong costo-colic ligament In addition it is often fixed by adhesions arising from the growth The latter is generally of the scirrhous constricting type and lymphatic metastasis is limited It is in these cases that a parietal incision directly over the growth

is invaluable When, as the result of previous exploration, the surgeon knows exactly with what he has to deal, an oblique incision about an inch below the costal margin and not less than six inches long, will give an admirable exposure Otherwise a cross cut may be made from a vertical incision (Fig 477, A)

Owing to the absence of a complete peritoneal coat, the difficulty of getting the ends together without tension, and sometimes doubt about the adequacy of the blood supply, these cases are not so suitable for local resection and end-to end anastomosis, and it is unlikely that there will be room enough for lateral anastomosis which requires a considerable overlap The secret of success is really adequate mobilization and the removal of much more bowel than the pathological state appears to indicate The ideal operation is to resect all that part of the intestine supplied by the left colic artery, with its mesentery and lymphatic drainage system, up to the origin of the artery, and to restore continuity by anastomosing the left end of the transverse colon to the upper end of the iliac colon, either by the axial end to end or the lateral method This may be greatly facilitated by freely mobilizing the iliac colon, especially at its upper end where it is often bound down, by dividing the peritoneal reflection between it and the postero lateral wall of the abdomen It is in these cases that a preliminary cæcostomy is so great a safeguard, and it if has not been done before, it is wise to make a valvular opening into the cæcum at the conclusion of the operation A rubber drain to the surface from the site of the anastomosis often saves a disaster These cases may be complicated by direct involvement of the surrounding viscera, but this is not necessarily an obstacle to successful removal This aspect of the matter is illustrated in Figs 475 and 488

Sigmoid flexure or iliac colon —Resection of a growth in this region is comparatively easy The flexure has a long mesentery, it is easily mobilized, it has a complete peritoneal investiture, and the growths tend to be of the constricting type without adhesions or extensive lymphatic involvement The only difficulty arises from the appendices epiploicæ, which may interfere with the accurate coaptation of the serous coat After preliminary mobilization, if this is necessary, *allowing the flexure to be well withdrawn from the abdomen, the* procedure followed is simple excision with end-to end axial anastomosis

There are those who recommend lateral anastomosis here, on the ground that leakage is less likely Lateral anastomosis has, however, two disadvantages (1) it needs a greater length of gut and therefore reduces the amount that can be removed, and (2) the proximal blind end may become distended and may ulcerate and even perforate Lockhart Mummery, who is a firm advocate of end to end union in the colon, considers that leakage is due to sloughing of the edges of the bowel where they are stitched together, and that this results from the circular type of arterial distribution to the wall, and can be obviated by cutting the bowel at an angle of 45° to its transverse

diameter Great care should also be taken not to seclude obvious vessels with the sutures, and the whole anastomosis should be protected by neighbouring appendices epiploicæ which should be fixed here and there over the suture line (Fig 460) A preliminary colostomy or cæcostomy is a great safeguard In every case, at the conclusion of the operation a tube should be passed through the anus into the rectum and fixed with a stitch to the anal margin

Pelvic colon —Removal of growths from the pelvic colon may be very difficult The growths whatever the type, tend to involve the lymphatic glands which may be invaded up to the origin of the inferior mesenteric artery There may also be extension to the pelvic peritoneum to the bladder or to the female pelvic organs Sometimes fixation is merely inflammatory, but in that case separation from the bladder or vagina may demand the greatest patience Resection should only be contemplated after preliminary colostomy, quite apart from any question of obstruction sufficient to demand that operation When the growth is very low *in the pelvis an inguinal colostomy will* suffice but for those more highly placed transverse colostomy is indicated

Unless the degree of obstruction demands blind colostomy, a deliberate exploration should be made at the same time as the bowel is drained For this purpose an independent mid line incision should be employed The oblique incision required for left inguinal colostomy can be enlarged and used for exploration but incisional hernia invariably follows, so that finally the colostomy comes to be perched on the summit of what may be a ventral hernia of considerable size

When the exploration discloses local extension of the growth to the peritoneum or surrounding parts only the experience of the surgeon can enable a decision to be made concerning the prospects of further intervention In many cases where there has been doubt of the nature of the mass it has subsequently turned out to be inflammatory The interval between the colostomy and the further intervention will depend on the degree of improvement in the patient's condition During the waiting period the lower segment of the bowel must be adequately cleansed but the growth should not be irritated, or stimulated to activity, by too vigorous interference, as physiological rest is important

When resection can be done the distal end is always short, and tends to be difficult to handle, owing to contraction and retraction There is a choice of four methods of dealing with the gut after resection (1) End to-end anastomosis by direct suture, (2) end to-end anastomosis by invagination, (3) making an artificial anus by fixing the proximal end to the abdominal wall through a separate incision combined with closure and infolding of the distal end, and (4) making an artificial anus with removal of the lower end, including the rectum and anus (abdomino-perineal) The type of operation can only be decided on after opening the abdomen, and depends upon the extent of the disease the accessibility of the lower end, and the degree of

mobilization of the sigmoid and descending colon which can be secured In all cases where end to-end anastomosis is contemplated the peculiarity of the circulation between the superior hæmorrhoidal artery and the inferior sigmoid artery must be borne in mind (Fig 487) In abdomino perineal operations where the whole of the intestine below the colostomy is to be removed it is safe to tie the inferior

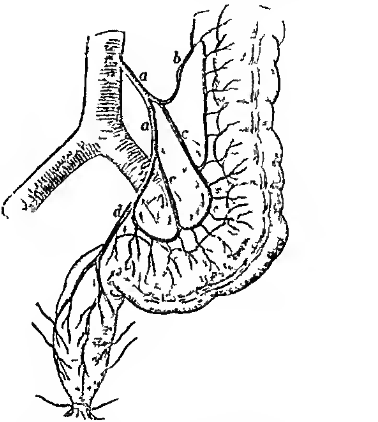


Fig 487 —Blood supply of iliac and pelvic colon
a Inferior mesenteric artery *b* left colic artery *c* sigmoid branches *d* superior hæmorrhoidal artery

mesenteric artery immediately below the left colic branch (Hamilton Drummond)

Enterectomy with direct end to end anastomosis—Spinal anæsthesia or combined spinal and general anæsthesia is a great help as complete relaxation is essential The patient is placed in the high Trendelenburg position and the abdomen opened in the middle line by an incision extending from the umbilicus or above it to the symphysis pubis The middle line is chosen because it gives the best exposure of the lower end of the colon The growth is examined and the scope of the operation determined The intestines having been packed upwards under swabs the first step consists in a colo parietal mobilization the peritoneal reflection from the colon to the posterior pelvic wall being divided parallel with the gut for a sufficient distance to permit of the

intestine being drawn up to or through the incision This may be extended so far as to free the lower part of the descending colon which is then wiped inwards until the middle line is reached In doing this the ureter may be freely exposed and must be safeguarded sometimes both ureters are seen As soon as the extra peritoneal tissue has been exposed the finger should be introduced behind the meso colon and gently thrust backwards into the hollow of the sacrum From that position gentle manipulation and forward pressure with the finger frees the bowel in a wonderful way and enables it to be straightened and drawn nearer the surface The inferior mesenteric artery is then defined a matter of no great difficulty if the gut is well mobilized and the mesentery not too loaded with fat It is tied immediately below the first sigmoid branch The lower ends of the coloparietal incisions are connected by a cross incision through the peritoneum covering the intestine below the growth In very low growths this connecting incision may encircle the whole of the bottom of the recto vesical or Douglas s pouch If this has not already been done the section to be removed is now freed from its attachments in the concavity of the sacrum by fingers thrust in behind it If there is room a clamp with a slight curve may be applied to the bowel before division but in many low growths this is not possible If steps have been taken to cleanse the segment of bowel below the colostomy and to empty the rectum the omission of the clamp is not a serious matter Sometimes the growth is so near the bottom of the recto vesical pouch that the bowel cannot be divided where it is covered with peritoneum In that case the mobilization may be carried on right down inside the levatores ani muscles until the bowel can be divided a sufficient distance below the growth entirely extra peritoneally In any case the surgeon must take care to make the division strictly horizontal When working deep in the pelvis the best plan is to open the anterior part of the bowel with a pair of scissors and then carefully cut through the wall section by section This provides an opportunity for removing any fluid from the lower end by the suction apparatus or by gauze swabbing Solid contents may be pushed down into the rectum with a strand of gauze This strand should not be withdrawn upwards but should be retrieved from the rectum at the conclusion of the operation As the upper end of the bowel is freed it may be caught in an angular holding clamp but the edges of the rectal end must be caught with catch forceps or guide sutures here and there as the division proceeds A few spouting vessels will have to be caught and tied The cut ends are protected and the mass drawn out of the abdomen The upper line of section is now decided upon and the gut is controlled by a clamp and divided all bleeding points being tied Traction sutures are placed on the lower end the surgeon waiting for a time to see if the cut edge bleeds in order to satisfy himself of the adequacy of the blood supply If the lower end is sufficiently accessible a direct *end to-end anastomosis* by double-suture line may be carried out the method being in no way different in plan from the ordinary end to-end anastomosis

When the lower end is below the level of the peritoneum, access is exceedingly difficult Small round, full curved needles used with a holder are essential The posterior part of the union should be made with mattress sutures, the remainder of the circumference of the bowel being united by a continous stitch If this is too difficult to apply, or there is disproportion in the size of the ends a few interrupted sutures may secure fair apposition This first layer must then be buried by further sutures passed Lembert-fashion despite the fact that the lower end is often without peritoneum After the union is completed it may be possible to provide further protection by drawing some of the pelvic cellular tissue or the pelvic peritoneum up to the bowel and fixing it by a few points of suture about the anastomosis It is essential that a thumb-sized rubber tube should be passed up from the anus to beyond the anastomosis and it is always wise to bring a rubber drain from the pelvis up out of the lower end of the abdominal incision If there has been much risk of soiling from the bowel or if the suture line is obviously insecure, it is better to pack the cellular tissue of the pelvis the suture line being protected from actual contact with the gauze by strips of rubber tissue This pack must be left for at least four days and should only be removed piecemeal Working at this depth, the union can seldom be accurately made and it cannot be expected to be watertight For this reason the operation should never be attempted in one stage and indeed is scarcely advisable except with the protection of a preparatory colostomy Nevertheless the union is often entirely satisfactory though a temporary fæcal fistula may occur The tube should be removed from the rectum at the end of a week, but no attempt should be made to close the colostomy until the abdominal incision is soundly healed, and this will probably be from four to six weeks after operation This operation is a serious intervention which has been attended by a considerable mortality but in cases that recover the after results are good and rectal function is completely restored Unfortunately, few deep pelvic growths are sufficiently localized to lend themselves to this method of upper conservative resection

Anastomosis by invagination—If the lower end is considered too short or too inaccessible to warrant an attempt at end-to end suture, *this second alternative may be adopted The steps are the same as* in the preceding operation up to the stage of anastomosis At this stage a thick-walled rubber tube, $\frac{3}{4}$ to $\frac{1}{4}$ in in diameter and 12 in in length, is firmly sewn into the upper end by catgut sutures The anal sphincter is stretched and a pair of ovum or similar forceps is passed up the rectum from the anus and enters the field of operation through the lower cut end The free end of the rubber tube is seized by these forceps and guided into the open lower end, the edges of which are steadied by temporary traction sutures By pulling on the tube in withdrawing the forceps, the upper bowel end is approximated to the lower, and when they meet they are sutured together with a few stitches of catgut A purse string suture is then loosely applied round the lower bowel end 1 in from the cut edge, and further traction made on

the rubber tube In this manner the upper end is made to invaginate into the lower, the purse-string is tied, and the union further strengthened by a series of interrupted Lembert sutures The tube acts as a splint and also as a channel for the passage of flatus and fæcal material, it is left *in situ* until the catgut sutures have absorbed This method, though it appears simple and satisfactory is not really easy to carry out As a rule the lower end cannot be made to invert and the principle of intussusception often fails The operation was originated by Rutherford Morison of Newcastle, and appeared to hold out great promise but in practice it has not fulfilled these expectations and is now very seldom employed Nevertheless, I believe that with a defunctioning colostomy it might suffice to approximate the bowel ends by means of the tube and to anchor them together with a few stitches here and there but without any attempt at invagination If gauze was then packed round about the area and brought out of the lower end of the incision, healing would probably prove satisfactory

In some cases the other alternatives may have to be adopted The upper end may be fixed to the abdominal wall through a separate opening in the left inguinal region, and the lower end either sutured over and left behind or removed altogether, with the rectum and anus The latter method is identical with the abdomino perineal operation for excision of the rectum (Vol II)

Permanent colostomy with closure of the lower end —The steps are the same as in the last operation up to the point where the growth has been cut away If an inguinal colostomy has been made, the whole of the bowel below should be removed If, on the other hand, a transverse colostomy or a cæcostomy has been the preliminary intervention, a separate incision is made in the left iliac fossa as for inguinal colostomy, and through this the open upper end of the bowel is drawn and fixed to the edges of the wound This open end, which will form a permanent artificial anus, may be temporarily closed, in order to prevent infection of the wounds by fæcal extravasation, or a Paul s tube may be tied in and immediate drainage instituted The lower end is then closed by a double layer of continuous suture, the inner layer passing through all the coats, the outer layer (seromuscular) being used to bury the inner The stump is then buried by sewing the peritoneum of the pelvic floor over it Sometimes it is difficult to close this lower stump on account of its depth in the pelvis or the obesity of the patient In either event it may be partially closed though not completely tucked in or oversewn In any case it is essential to drain the rectum with a large tube through the anus Probably a safer method is to pack iodoform gauze into the open rectum, one end being allowed to protrude from the anus When possible the pelvic peritoneum is sutured over the gauze but this is not essential, though when it cannot be done the omentum should be packed into the pelvis over the gauze At the end of the operation the anus should be well dilated The gauze is removed piecemeal,

commencing about the fourth day and ending by the seventh day This method has frequently been employed and is quite reliable

GROWTHS INVOLVING OTHER VISCERA OR THE PARIETES

In all such cases the final decision whether a radical removal can be undertaken will depend upon a preliminary abdominal exploration If evidence of distant dissemination is absent, then no degree of local extension should deter the surgeon from at least considering the possibilities of removal This type of case demands multiple-stage intervention but whether that must take the form of a preliminary colostomy or an anastomosis will be decided by the degree of obstruction and the situation of the growth The improvement which may follow such a preliminary intervention is the best guide to the probable success of the major operation Where the abdominal wall is directly invaded by an extension of the growth an elliptical portion of the whole thickness must be excised and care must be taken to secure a sufficient margin of healthy tissue beyond the edge of the growth It may be difficult to repair the defect in the parietes completely but every endeavour must be made to provide at least a skin covering, even if it is necessary to raise a flap for that purpose A considerable part of the wound may have to heal by granulation, and an incisional hernia will probably result, but that is the price the patient may have to pay for the chance of freedom from recurrence When the *small intestine* is involved it is usually best to excise the affected coil completely together with the colon growth, restoring continuity by end-to-end suture When, on the other hand, the growth is involving some other portion of the *colon* by direct extension it may be perfectly safe and efficient to cut out a portion of the wall of the bowel to which the growth is adherent This may leave a large window, but it can always be safely repaired If the extension is to the lateral aspect of the large bowel or impinges on the mesentery, then nothing but a resection of the involved portion will suffice The same considerations apply when the *stomach* is the organ involved, and it will seldom be necessary to do a cuff resection, for quite a large portion of the stomach wall may be excised and comparatively easily repaired When the *spleen* is concerned it is much wiser to excise the whole organ together with the growth In the case of the *kidney* it is sometimes quite satisfactory to incise the capsule well away from the point where the growth is adherent If the capsule can then be readily stripped from the kidney it is good evidence that the removal of the adherent portion of capsule is all that is necessary When, on the other hand, the capsule will not strip, the kidney should be removed with the mass Growths of the hepatic flexure sometimes involve the *gall-bladder* which can be excised with the tumour When the *liver* is directly invaded the affected portion may be removed by wedge-shaped excision, but if only the extreme edge is involved then it may suffice to slice off the affected portion (see p 772) With the *pelvic viscera* the difficulties

may be greater for there is a tendency for the peritoneum of the pelvic wall to be involved over a considerable area But even in these cases it is often possible to remove all the affected parts though restoration of the continuity of the bowel may have to be omitted a permanent colostomy being substituted

Cases complicated by *vesico-intestinal fistulæ* are especially difficult as it is necessary to excise the portion of bladder surrounding the actual fistula Those situated high up on the posterior surface of the bladder can usually be managed To make a clean sweep an area of bladder wall about half an inch on all sides of the fistula must be removed The bladder is opened at a convenient spot and the surgeon carefully cuts out the affected portion using the scissors or diathermy knife Sometimes the bowel growth is so bulky that it completely obscures the site of the fistula In these circumstances it is best to separate the growth from the bladder and with this out of the way to deal with the latter unimpeded Though this plan is not ideal it may be the best method of completing the operation The defect in the bladder must be repaired by catgut sutures taking a good hold and penetrating all but the mucous membrane After these operations a catheter must be left in the bladder *per urethram* and the pelvis should be drained with a rubber tube the patient being nursed in the Fowler position for the first few days

Many of these extensive multiple resections do well the patients surviving in comfort for years (Figs 475 488)

Results —Many factors influence the results of operations for cancer of the colon and like all interventions for intra abdominal malignant disease the immediate mortality is often a reflection of the risk the surgeon is prepared to take in the hope of conferring the maximum benefit on his patients

When the disease is complicated by obstruction the mortality is very considerably diminished by intervention in stages So much does this apply that I am always glad to have an excuse for carrying out preliminary bowel drainage and completing the excision at another stage Growths that have invaded the parietes or neighbouring viscera are always more difficult to deal with but given a patient who has been adequately prepared even multiple resections are not in themselves especially dangerous Whatever the method employed it is necessary to exercise punctilious care in carrying out the operative details and the whole intervention must be conducted under the guidance of the eye It is significant that those cases in which the growth has been complicated by abscess formation often do extremely well

Up to the end of 1931 I had operated on 279 malignant cases in 165 the growth was excised with an over all mortality of 18 per cent In 107 cases operated upon since 1919 the mortality was 11 per cent In 147 continuity of the bowel was restored and in 18 after resection the patient was left with colostomy The series included many double and complicated resections

I was able to review 115 of the after histories 11 died of recurrence

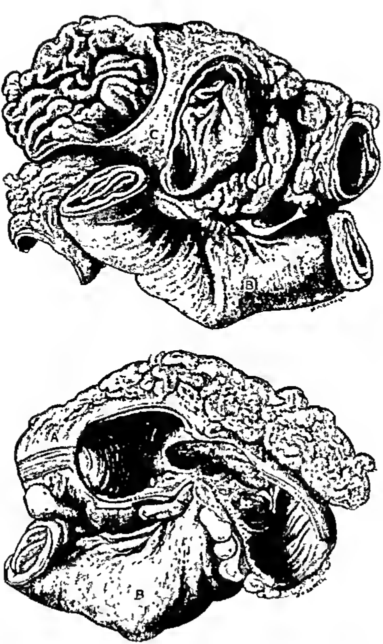


Fig. 488.—Carcinoma of the colon (A) involving a loop of jejunum (B) and a portion of the stomach (C). A two-stage operation, with triple resection and restoration of continuity, was followed by complete recovery. The man enjoyed good health for three years, and then died from another cause, without recurrence.

(Reproduced by permission from The Lancet.)

within 5 years, and 64 were alive or had died without recurrence at periods up to 15 years after operation. In Lockhart Mummery's series, 41 cases were operated upon more than 5 years previously and of these 20 were alive and free from recurrence. Out of 42 cases traced

by Sir Charles Gordon Watson 15 were alive and well over 5 years The Mayo Clinic estimates that 50 per cent of those surviving the radical operation will be alive and well 5 years later

An average mortality of 12 to 15 per cent probably reflects the results of any group of experienced surgeons today If that could be reduced to 5 per cent in a considerable series including all parts of the large bowel and all types of case then it would certainly represent the acme of judgment and perfection of technical skill Some surgeons have attained even better success in fortunate runs of operations but they are unlikely to continue to enjoy such comforting rewards as the number of their cases increases I have more than once set out with the determination to carry out a century of colectomies without a death but after encouraging runs of successes one or more deaths sometimes consecutive have marred the record and I have never attained my ideal *Probably the extra abdominal method is the safest* so far as immediate results are concerned but there are operable cases for which it is not suitable and in a good many cases the after result is spoilt by local recurrence in the abdominal wall Some indication of the *operative mortality* is furnished by the following figures — Gordon Taylor had a series of 126 extra abdominal excisions with only 5 deaths C F Dixon of the Mayo Clinic reports a mortality of from 8 to 12 per cent but several of the operations were for non malignant conditions

TOTAL COLECTOMY

This operation is very seldom indicated and is now infrequently performed Multiple malignant growths polyposis multiple injuries such as may occur in warfare and certain congenital anomalies (like mega colon which has not responded to sympathectomy) may all *require complete removal of the colon* It would also seem rational to consider the operation in those very acute varieties of ulcerative colitis in which the whole of the large bowel is involved and life is seriously threatened It may be carried out in one or more stages and the general condition of the patient the necessity for bowel drainage and the disclosures of an exploration will determine which method is to be employed In any event the operation is of considerable magnitude and in all cases a careful watch must be kept on the blood pressure so that suitable measures may be adopted to anticipate shock For the actual excision it is necessary to have a sufficient exposure and usually a midline or left para median incision extending from an inch or more above the umbilicus down to the pubes is satisfactory The first step is to deal with the great omentum which should be preserved whenever possible In malignant growth in the transverse colon or at the flexures the part of the omentum in relationship to the neoplasm must be excised In other cases the omentum should be turned up and its avascular attachment to the colon completely divided with the scalpel close to the bowel It is next necessary to mobilize the colon by dividing the membranous

bands and adhesions on its outer side. These are much more fully developed about the cæcum, hepatic flexure, splenic flexure and sigmoid, and they should be systematically and freely divided under the guidance of the eye. When there is no question of malignant disease, the division may be made close to the bowel in order that the exposed retroperitoneal area which will be left may be as small as possible. In many of the bands there are vessels, and though none of these may individually account for much hæmorrhage, in the aggregate a considerable loss of blood may occur unless they are caught and ligatured. It is therefore best to clamp the bands with artery forceps before dividing them and to take care to apply ligatures in every case. After mobilization in this way the colon can readily be separated from the extraperitoneal tissue by gauze stripping and thrust gently towards the centre of the abdomen. This having been done, the next step is to divide the mesenteries and secure the vessels. These structures may be dealt with before the bowel is cut across, or the division of the ileum may be regarded as the most convenient method of approaching the mesentery, from which point the control of the vessels may be commenced In thin subjects the first method is quite easy and satisfactory but the mesentery of the corpulent may be more safely approached by the second plan.

It is not necessary to detail the various methods by which the vessels may be secured, but it is important to emphasise the risk of overlooking a vessel which, when divided, may quickly retract and bleed. Every bit of mesentery should be included in the ligatures and a sharp look-out must be kept for what may appear to be tiny vessels which might escape. If the method of transfixion is used care must be taken not to puncture vessels The instrument used for transfixion should have a blunt point and should be made to worm its way through the mesentery rather than be quickly thrust through. The mesentery may be caught and divided close to the bowel, but the amount of tissue to be ligatured can be diminished by securing the vessels some little distance away from the edge of the bowel. When the mesentery is very fat, vessels easily retract and in that way escape ligature; to avoid this accident the tissues should be cut at least half an inch beyond the point at which the ligature is to be applied and it should be securely tied before the artery forceps or clamp is removed, though the latter should be carefully loosened in order that the ligature may secure a better bite If hæmatomas form in the mesentery they must be investigated at once.

When the second method is adopted, the ileum is divided about six inches above its termination and, having protected the open ends, the surgeon proceeds systematically to clamp and divide the mesentery right round until the sigmoid is reached. The amount of sigmoid to be removed will depend on the pathological condition but, generally speaking, the more sigmoid that can be preserved the better will be the functional result. The vessels having been carefully ligatured and all potential sources of bleeding systematically considered, the con-

tinuity of the bowel can be safely restored by making an end anastomosis between the open end of the ileum and the sigmoid This should present no difficulty and is certainly as safe and satisfactory as a lateral or side to side union If the latter has already been made at a first operation then it is only necessary to divide the ileum and sigmoid and securely tuck in the ends care being taken not to leave long blind cul-de-sacs beyond the point of the anastomosis

If a preliminary cæcostomy or colostomy has been made then the first stage of the intervention should take the form of a rough closure of such an opening This can be done by making an incision through the skin around the fæcal fistula about ¼ in from its margin and then undercutting the skin to form a fringe which can be tightly sutured over the fistula This having been done the adjoining bowel must be freely separated from the parietes and returned to the abdomen after which the operation is conducted as in an ordinary case The defect left at the site of the cæcostomy must be sutured in layers either there and then or as a last stage in the operation When the anastomosis has been completed all areas denuded of peritoneum should be covered as far as possible *No slavish attempt must be made to drag parts together at great tension and especially does this apply to the cut mesentery with its vessels* If peritoneal edges cannot be approximated they can often be partially drawn over bare areas and then fixed to the posterior abdominal wall with an odd stitch here and there As a last step the omentum should be drawn down over the small intestine The abdomen is closed without drainage

Arbuthnot Lane used to lay stress on the importance of passing a tube from the anus up through the anastomosis into the small intestine but this is often difficult to accomplish and of doubtful advantage But it is useful to leave a tube through the rectal sphincter to guard against the accumulation of flatus

In operations for ulcerative colitis it is important to remember that the ulcers are multiple and that very often they are on the point of perforation so that any but the gentlest handling may precipitate this calamity Total colectomy has sometimes been recommended for the very acute type of this disease In these circumstances the ileum must first be divided the upper end being fixed in the wound as an ileostomy The large bowel is then removed as already described Previous investigation will have disclosed the condition of the rectum and lower sigmoid When the disease is not very well marked in these parts the division should be made about the middle of the sigmoid so that at some subsequent time the ileum may be united to this part of the bowel to restore the continuity of the canal Any residual ulceration in the sigmoid or rectum will probably heal as the result of physiological rest and in any event can be suitably treated *per rectum*

Appendicostomy aims at providing a ready means of irrigating the colon and has from time to time enjoyed much popularity in the treatment of colitis Among careful surgeons the method is recognized

as a useful adjunct in the management of this troublesome disease (For technique, see p 897)

Multiple polyposis may be attended with so much, or such continuous, hæmorrhage from the bowel that there is intense anæmia If this does not respond to preparatory measures, including, of course blood transfusions, it is essential that the operative treatment should be carried out in stages first, a cæcostomy or, in very bad cases, terminal ileostomy After the full benefit of physiological rest has been secured, which will only be after some months, the second stage may be carried out This consists of removal of the bowel from the point where the ileum was divided to the sigmoid The site of division of the latter will depend on the location of the polypi in the lower colon as determined by previous investigation As a third stage polypi within the reach of the sigmoidoscope are removed through that instrument from the remaining pelvic colon and rectum The fourth and last stage consists in the restoration of the continuity of the bowel This may be done by making a lateral union between the ileum and the remaining pelvic colon a short distance above the ileostomy, but it is quite feasible to detach the latter from the abdominal wall and to make an end to-side anastomosis When the method of lateral anastomosis has been used, a fifth stage consists in the excision or closure of the ileostomy Where there are great aggregations of polypi in the rectum and pelvic colon it may be necessary to remove those portions of bowel as in the abdomino-perineal method of excision of the rectum This would mean leaving the patient with a permanent ileostomy and only the gravity of the prospect of the development of malignant disease in the remaining polypi can justify such a step

Removal of single polypi.—These adenomata may occur in the large bowel above the rectum They are usually of considerable size, perhaps anything from ½ in to 2 3 in in diameter The larger polypi often have very short stalks and are almost sessile, in which case it is much wiser to excise the portion of bowel in which they arise, and this especially applies to those cases in which the growth is on the mesenteric side The smaller polypi, on the other hand, usually have *quite long stalks, and in these circumstances they may safely be* locally removed The portion of bowel in which the polypus is arising is withdrawn from the abdomen, which is carefully packed off The lumen is then opened by incision along the anti-mesenteric border over the site With the incision in the bowel held well open, the polypus and its attachment may be withdrawn from the interior so that the base is well exposed An ellipse of mucous membrane is then excised, together with the base of the stalk After the mucous membrane is incised all round, it will be necessary to apply a ligature to the vessels entering the stalk and then to repair the bowel wall with a few interrupted sutures, taking a good hold of the submucous tissue as well as the mucous membrane The outer aspect of the bowel opposite the point of attachment must be inspected and if

necessary protected by the insertion of one or two Lembert sutures The incision made into the bowel for the exposure of the polypus must be repaired in the transverse axis so that there can be no question of diminishing the lumen

Tuberculosis.—The only condition in which operative interference is likely to be called for is in the so called massive tuberculosis of the cæcum This is sometimes associated with chronic intestinal obstruction while in other cases the symptoms are more of local inflammatory trouble often with sinuses or fæcal fistulæ over the site of the disease In either case the patients are often in poor condition None the less the disease is usually localized and the results of surgical removal have been encouraging It is most important that the patient should

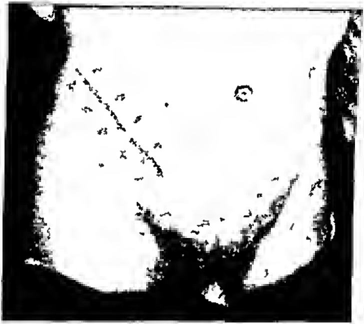


Fig 489 —*Incision for removal of cæcum for tuberculosis*

be properly prepared by attention to sepsis and anæmia In most cases a two stage intervention is best and this should take the form of a preliminary short circuit When there is no marked obstruction the ileum should be divided above any obvious disease usually about a foot away from its termination The lower end is completely closed while the proximal end is joined to the colon beyond the hepatic flexure by the end to side method On the other hand if the ileum is much distended a lateral anastomosis to the colon is safer

Occasionally so much benefit follows the relief of the obstructive symptoms that further intervention is not indicated When there is a considerable mass especially if associated with outbursts of pyrexia or there are sinuses or fæcal fistulæ the best hope lies in a well planned excision For this second operation emphasis must be laid on the

advantages of an incision directly over the affected site (Fig 489), for only in this way is it possible to deal with the fixation under the guidance of the eye If there are sinuses or fistulæ these should be excised with an ellipse of the abdominal wall which can be readily included in the oblique incision recommended As a rule the lymph nodes in the ileocæcal angle are invaded with tubercle and it is much wiser to remove them together with the bowel If an anastomosis has not already been made, the ileum should be divided about a foot above the cæcum and the ileocæcal angle removed, together with the cæcum, ascending colon and hepatic flexure In making the anastomosis there must be no blind end to the ileum, as this is apt to harbour tubercle bacilli with the development of secondary fæcal fistula Direct end-to end union of the ileum to the colon is best, but if the ileum has already been divided and joined to the colon the latter should be divided and tucked in close to the anastomosis in order to avoid a cul-de-sac

After operation it is necessary for the patient to have a long period of convalescence under the best conditions that can be provided so that any residual tubercular disease may become quiescent and eventually heal This period has to be counted in months rather than weeks, and six months to a year is certainly not too long for the purpose

Impaction of foreign bodies.—The only foreign body likely to be met with is an impacted gallstone, and this is exceedingly rare When it does occur it is nearly always in the sigmoid, but calculi so enormous as to become arrested in the transverse colon have been known * In some cases the condition has been diagnosed as obstruction from new growth and has been treated by cæcostomy, which is probably the best thing that could happen For the actual removal of the calculus an incision has to be made along the longitudinal band over the site of the gallstone, and this should be long enough to allow the calculus to be removed without damaging the wall of the bowel This incision must then be sutured in the opposite direction in order to diminish the narrowing of the bowel which might otherwise occur

Partial colectomy for diverticulitis.—When this is required it is usually the sigmoid or pelvic colon which is affected The operation is undoubtedly much safer if it is done as a second-stage intervention after preliminary bowel drainage and, usually, colostomy of the disfunctioning type The technique required is in general the same as in operations for new growth but is often a great deal more difficult, for there is usually much more local inflammatory fixation which complicates the mobilization Small abscesses may also be encountered It is not necessary to make any wedge-shaped excision of the corresponding mesentery, although it is well to remove enlarged lymph nodes which might harbour infection The actual anastomosis should be carried out at a point free from diverticula but this is not always easy to determine, especially when the colon is loaded with

*Grey Turner *Brit. Journ Surg* 193* No 77, xx, 28

fat In these circumstances it is a good plan to dissect away the fat from about half an inch of either bowel end this may expose hidden diverticula Should a diverticulum be encountered when making the division of the bowel great care should be taken to remove it before the bowel is sutured This may entail a considerable dissection and may lead to some irregularity in the margin of the bowel but this is of much less moment than the risk of leaving part of the lumen of a diverticulum exposed to the peritoneum The anastomosis should be most carefully protected with the adjoining appendices When there is a communication with the bladder the bowel is separated from that viscus and the fistula closed by suture This may not be easy on account of inaccessibility or because the bladder wall is too much indurated about the margins of the fistula. In these circumstances the aperture may be plugged with omentum or neighbouring fat fixed by a stitch In any event the bladder should be drained by catheter and the pelvis by a tube It is wise to pass a large tube through the anal sphincter and leave it *in situ* for at least four days During this time the patient should be nursed in the Fowler position

CHAPTER XXII

OPERATIONS FOR APPENDICITIS AND PERITONITIS

By G GREY TURNER

I APPENDICITIS

INFLAMMATION of the appendix vermiformis is responsible for the large majority of acute abdominal conditions and in its subacute or chronic phases it may give rise to many forms of ill health The usual tendency in appendicitis is towards recurrence Between attacks patients may be perfectly well or may suffer in various ways e g indigestion abdominal pain chronic toxæmia As the result of recurring inflammation a stricture may form in the wall of the appendix leading to retention of secretion in the distal end or the walls may become thickened and the lumen stenosed Adhesions to neighbouring structures may cause much trouble There is also evidence of some sympathy between the pyloric sphincter and the ileo cæcal valve and chronic inflammation of the appendix may have a causal relationship to pyloric spasm and to duodenal ulcer *

The appendix is also subject to certain diseases such as tuberculosis actinomycosis and adeno carcinoma and may be secondarily affected in peritonitis originating elsewhere Threadworms are not infrequently present in its lumen sometimes giving rise to a subacute type of infection and roundworms may cause acute gangrene Foreign bodies (such as shot or bristles) are found occasionally and fæcal masses are common the latter possibly determining perforation in some acute infections

An acute appendicitis may follow several courses If drainage into the cæcum is satisfactory the inflammation may resolve if there is indifferent drainage the appendix may become distended with pus (empyema of the appendix) and burst causing gross infection of the peritoneum in the vicinity or diffuse peritonitis Should the infection be very acute gangrene and sloughing of the appendix may occur or the vessels in the meso appendix may become thrombosed and be the cause of portal pyæmia In a less virulent infection the inflamed appendix may become wrapped in omentum or walled off by adhesions so that if an abscess occurs it may for a time at least be definitely localized

The anatomical position of the appendix has an important bearing on its surgical management For the most part the organ lies in the sulcus on the outer side of the cæcum In a certain proportion of cases it lies behind the cæcum so that the consequences of inflammation are apt to be hidden by *that part of the bowel* When there is suppuration the abscess may extend behind the colon for a considerable distance

* B al hwa e L R *B t Journ Sur* 191 No 117 xxx 15

and may even come in contact with the second part of the duodenum into which it has been known to discharge. When the appendix lies on the outer side of the cæcum and is directed upwards the inflammatory products may collect in the right loin pouch (Morison's pouch) and may impinge on the under aspect of the right lobe of the liver or may creep over the upper surface of that organ. When the organ lies in the opposite direction it may reach the pelvic brim or hang over it and may even touch the bottom of the recto vesical or Douglas's pouch. In other cases it may lie along the ileum or it may pass up behind that part of the small bowel so that its tip points into the midst of the small intestine area.

When arising in the pelvis the products of the inflammation may localize there or may overflow into the abdomen. In the latter event they tend to travel *via* the sulci on the outer side of the colon either into the right loin pouch or the corresponding position on the left side and from either situation the path to the liver and spleen pouches is usually unimpeded. In other cases the infection may directly invade the small intestine area from the pelvis and when that occurs a general infection of the peritoneum almost certainly follows. General peritonitis is very probable when the appendix lies in the small intestine area. The base of the appendix is the only part of the organ which can be said to have any more or less fixed position and is indicated by McBurney's point.

The *age* of the patient and *the recurrence or otherwise of previous attacks* influence the course of the disease. It is the usual experience that diffuse peritonitis is more common as the result of the first attack than of subsequent attacks and that if recovery takes place from the first there will certainly be recurrent attacks at gradually shortening intervals. Any one of these attacks may be severe but the general tendency is for the severity to decrease though the attacks become more frequent. The influence of age may be summarized in the formula "The younger the patient the graver the disease". (*See* p. 976.)

In children the appendix is relatively large and its walls are thin especially the submucosa so that perforation occurs rapidly and there is less tendency to localization partly because the appendix more often lies among the intestines in children than in adults and also because the peritoneum is less resistant. In addition to these facts the diagnosis of appendicitis and particularly the differential diagnosis is much more difficult in children.

Attacks of colicky abdominal pain are common in early life, vomiting is not infrequent and pyrexia is an uncertain guide. Children under 10 years of age or so have little sense of localization of pain and all abdominal pain is referred to the umbilicus but intelligent observation will discover that the most marked tenderness is over the seat of the appendix. Even in pelvic appendicitis tenderness can nearly always be elicited low down by the side of the right rectus muscle and little children will often accurately indicate the site of tenderness if they are encouraged to cough.

Some of the most difficult problems are met with *in acute diseases of the chest*, causing abdominal pain and rigidity Attention was first drawn to these cases in Great Britain by the late H L Barnard, and the condition is now well recognized and often discussed, but errors still occur The mistake used to be to overlook the chest complaint and operate for a supposed acute appendicitis Now, so much alive is everyone to the possibility of error that the tendency is to diagnose as acute chest conditions what are really acute abdominal conditions, and thus to miss the chance of early intervention A rectal examination may be very valuable and is so important in children that no abdominal examination should ever be considered complete without it

Among other conditions which must be differentiated from acute appendicitis in children are pneumococcal or acute tuberculous peritonitis, acute indigestion intussusception and other forms of intestinal obstruction, and Henoch s purpura An appendix abscess in a child may cause flexion of the hip and lead to a diagnosis of joint disease The most difficult disorder to differentiate from chronic appendicitis in children is tuberculous disease of the mesenteric glands, but fortunately the difficulty is of little importance as operative interference is usually indicated (*See* p 1010)

Acute Appendicitis

Indications for operation.—The view widely held, that operations should be carried out as soon as an acute appendicitis is diagnosed, has everything to commend it but, like all generalizations has been subjected to much criticism That the mortality of acute appendicitis increases steadily with delay in operating is undoubtedly true, and if all cases could be operated upon while the disease is still limited to the appendix or its immediate neighbourhood many lives would be saved But many cases are not seen until perhaps the severity of the attack is beginning to decline, and it is then that difficulties in diagnosis occur and differences of opinion arise over proper management

The late Professor Sir David Wilkie of Edinburgh drew attention to what he considered the essential difference between acute obstruction of the appendix, which is so likely to lead to gangrene with its consequences, and primary inflammations which often go on to resolution or to localized abscess He suggested that in the first group operation is imperative, while in the second the surgeon may often stay his hand until a convenient opportunity While this distinction is of much academic interest, it is apt to be dangerous as a guide to management for nothing should be allowed to countenance delay in operating Another school is largely guided by the time which has elapsed after the onset of an attack They measure *pathological* progress by the clock and make it a guide to treatment These surgeons advocate delaying operation in all cases that are not seen until 36 hours after the onset It is claimed that the majority then safely subside and localize and that the delayed operation is attended by a lower mortality, a lessened incidence of complications,

and a shorter stay in hospital Most cases of appendicitis require operative treatment but the urgency varies and whereas in very acute rapidly progressing cases the surgeon must know no night no day there are others in which convenience may play a part in deciding when the operation should be performed Again there are cases especially with abscess formation in which the patient is so profoundly toxic or suffering so much from acidosis that a delay of some hours is absolutely essential in order that these conditions may be combated There are also many desperately ill cases with unlimited peritonitis in which the extent of the interference and its technique must both be modified and in such the mere incision of an abscess under local anæsthesia may be life saving whereas a classical operation with a search for the appendix may be as good as a death warrant It must always be remembered that simple drainage will often save life and that the appendix can be safely left for subsequent removal

For many years I have found it convenient to classify cases in the following groups —

Group 1 Acute appendicitis without peritonitis
Group 2 Acute appendicitis with localized peritonitis
Group 3 Acute appendicitis with flank or pelvic peritonitis or both
Group 4 Acute appendicitis with diffuse peritonitis
Group 5 Appendicitis with residual abscess
Group 6 Appendicitis with primary localized abscess
Group 7 Appendicitis—interval removals
Group 8 Appendicitis with primary complications
Group 9 Appendicitis—no operation
Group 10 Appendicitis—incidental removals

There is no classification of appendicitis that is not open to error and to which objections cannot be raised but this simple grouping has proved both useful and practical The basis of the classification is a pathological one The disease starting in the appendix spreads as a radiating infection and in the great majority of cases at its inception it is entirely local

Groups 1 and 2 would naturally include the very early cases that is to say those seen probably within twelve to twenty four hours

Group 3 includes patients who may have only been ill for perhaps twenty four hours but with the same extent of inflammatory extension other patients may give a history of an illness extending over a period of two to three days

Group 4 would ordinarily be looked upon as only a later stage of group 3 but that is not always in accordance with what actually happens for the acuteness of the inflammation and the rate of invasion of the peritoneum vary very considerably

Group 5 was introduced for a class of case which is not often encountered at the present time but which used to be quite frequent some years ago when the need for early surgical interference was not so well recognized as it is to day Such patients usually give a history of

having passed through an attack of general peritonitis and reached a stage in which recovery has come to a standstill In these circumstances it is not uncommon to find a collection of pus in the pelvis, in one or other flank, or between the coils of the small intestine Such abscesses have to be distinguished from those that remain localized about the appendix wherever that organ happens to be situated These latter cases form group 6 The cases included in group 7 are those in which there is no active inflammatory trouble but in which the evidence of a lesion in the appendix is unmistakable Sometimes they are spoken of as interval or cold ' cases From the operative point of view they are in an entirely different category from all the others and for that reason their management is considered separately

Group 8 is introduced to include cases where the acute appendicular mischief is complicated by such conditions as portal pyæmia (pylephlebitis) intestinal obstruction or some acute chest mischief

For groups 1, 2 and 3 there is now general agreement that immediate operation is the only proper course None the less, there are cases in which the symptoms so rapidly improve that the question of deferring the operation may be raised but this is dangerous Even when an attack does safely subside there is an invariable tendency to recurrence, and therefore the surgeon must always urge that the evil day is only being deferred and that the next attack may come on at a much more inconvenient time

In group 4, though some type of operation is demanded, there may be very good reasons for deferring the interference for some hours to institute treatment directed to improve the general condition In these cases the patient may be so desperately ill that the scope of the operation may have to be limited and mere incision over the appendix region for drainage may be the only measure permissible in the hope of saving life

In group 5, again, an operation is usually required, but only for the evacuation of the abscess wherever it may happen to be In the majority of cases in this group removal of the appendix must await a later intervention when all signs of active inflammation have subsided

In group 6 operation is essential, but the scope of the interference may be varied On many occasions it may be possible to open the abscess and to remove safely a very accessible or easily-found appendix, while in others it may be very much wiser merely to drain the abscess in the first instance leaving removal for later intervention during a quiescent period after the lapse of three or four months During this waiting period it is not necessary for the patient to remain an invalid, but he must be warned that, should there be any recurrence of pain or other evidence of activity, immediate surgical intervention may be required The greatest difficulty occurs in those cases in which the severity of the symptoms are waning when the patient is first seen and there is only a slightly tender but extremely hard mass in the iliac fossa In such cases there has probably been an appendix abscess which has leaked into the bowel or in which the subsiding inflammation

has been followed by the development of very dense inflammatory tissue, perhaps enclosing a collection of inspissated pus In this group it is best to keep the case under observation and, if *all* the symptoms are improving and the mass is gradually disappearing, it is well to continue to defer operation until there is nothing but remaining tenderness to indicate the pathological change which has been present This will usually necessitate a delay of from four to six weeks

Group 8 will always demand the earliest possible intervention but the prognosis will depend more on the associated complication than on the condition of the appendix

Appendicitis in children and in the aged is a matter of extreme urgency At the beginning of life this is generally recognized, but at the other extreme there is a tendency to put off and to hope that the condition will subside and operation be avoided But many lives are lost in this way and there is much less risk in advising early intervention than in countenancing delay The *difficulties in diagnosis* must be acknowledged but many cases even in extreme age are quite unmistakable

After these observations it may be laid down as a general rule that *every case of acute appendicitis should be operated on as soon as possible after diagnosis* In the majority of cases there is no difficulty in arriving at a correct diagnosis, not only that the appendix is at fault but also of the extent of the pathological processes associated with it On occasion there may be uncertainty, but the properly trained surgeon will never fall into the error of supposing that every patient with pain referred to the right iliac fossa is necessarily suffering from appendicitis It is not possible within the scope of this work to discuss the problems of differential diagnosis but it may be reiterated that the most valuable sign of appendicitis is easily-elicited tenderness over the appendix area

Indications for removal of "quiescent" appendix.—There is so marked a tendency for the appendix which has once become inflamed to suffer from recurrent attacks that the question arises whether it should be removed after the first attack It is now the general opinion that this is correct While it is safe to predict that if not removed relapses will occur, it is impossible to give any opinion on the probable interval, the severity of future attacks or the menace to life But the risk attached to a relapsing appendicitis does not consist solely in the danger of acute exacerbations In the intervals between the attacks, and often without any marked attack, a pathological appendix may be lowering the health of its host Many patients never quite lose their pain and suffer from epigastric discomfort, flatulence, constipation and the so-called "appendix dyspepsia" In others, adhesions give rise to dragging pains and perhaps to delay in the ileum

Both duodenal ulcer and cholecystitis have been considered to result from appendix infection *B coli* infections of the urinary tract or chronic or subacute arthritis may be the result of absorption from the appendix and there may be other evidences of infection

Preparation for operation.—*In acute cases* it may be necessary to adopt measures such as are used in peritonitis to combat the toxic effects of intra-abdominal inflammation (p 997) Patients will be more comfortable during the immediate post operative period and after-treatment will be facilitated, if the lower bowel has been cleared Purgatives must not be administered and only a small enema can be permitted Usually there is too much tenderness to permit proper local preparation of the operation area and this should be carried out in the theatre after the patient has been anæsthetized *In interval*

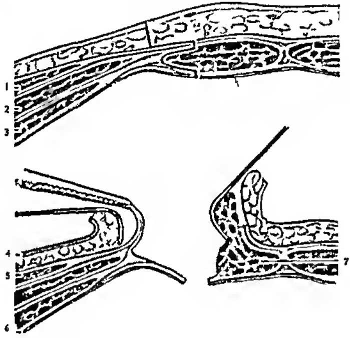


Fig 490—Appendicectomy by Battle's incision structures divided
1 External oblique 2, internal obliquus 3 transversalis 4 skin 5 aponeurosis of external oblique 6 transversalis fascia and peritoneum 7 rectus abdominis muscle.

cases the usual preparation for any abdominal operation should be employed

Anæsthesia.—Unless there is some active chest trouble general anæsthesia can be safely employed Post-operative chest complications are unusual, probably because the intervention is limited to the lower quadrant of the abdomen It is necessary to warn against the use of chloroform in the acute cases, as serious liver changes with fatal acidosis may result Spinal anæsthesia is quite satisfactory, and local anæsthesia can be employed, but with the latter method the patient may be subjected to a good deal of pain during the separation or delivery of the appendix and especially in the acute cases

Technique —*Incisions* —The incisions usually employed are either more or less vertical through or by the side of the rectus muscle with temporary displacement of that structure or oblique and directly over the appendix

Some operators favour a transverse incision low in the iliac fossa but this approach has never been generally adopted

1 *Battle s incision* is made parallel with and a little median to the right semilunar line its centre being placed directly over the suspected position of the appendix (Figs 490 491A) Its length varies with the thickness of the abdominal wall but should not be less than 4 in The

Fig 491 —Appendicectomy incisions

(A) Retrorectus (Battle s) *(B) gridiron (McBurney s)*
(C) Rutherford Morison s (D) median sub-umbilical

aponeurosis of the external oblique is divided in the line of the skin incision the anterior sheath of the rectus abdominis is opened and the outer edge of the muscle exposed and retracted towards the middle line (Fig 491) The posterior sheath of the rectus is then divided in the same vertical line as the incision in the anterior sheath and the peritoneum opened It is important to try to spare the branches of the 11th and 12th intercostal nerves which cross the field from above downwards and inwards It is sometimes possible to retract these structures out of harm s way At the lower angle of the wound the deep epigastric vessels passing from below upwards and inwards

should be avoided The peritoneum is opened for the distance which the condition demands

The wound is closed if drainage be not employed by three layers of suture The first a continuous catgut suture unites the peritoneum and posterior sheath of the rectus the second an interrupted catgut unites the anterior sheath *and the aponeurosis of the external* oblique on the inner side to the aponeurosis of the external and internal obliques on the outer side Interrupted silkworm stitches are usually employed for the skin and subcutaneous tissue If drainage is necessary

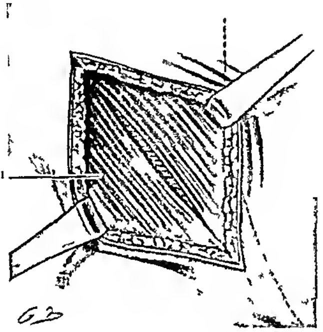


Fig 492A.—Appendicectomy by McBurney's muscle separating incision

1 Aponeurosis of external oblique. The dotted line indicates the outer border of the rectus To clarify the incision depicted as longer than it usually made

it is usual to make a small independent incision through the parietes *in the iliac fossa or even the right flank Of course the drain* may be brought directly through the lower end of the incision but this route invites subsequent hernia

2 McBurney's incision* is made obliquely at the junction of the middle with the outer third of a line joining the umbilicus with the anterior superior spine (Fig 491 B) The aponeurosis of the external oblique is exposed and a way made through it by separating its fibres which run practically parallel with the incision (Fig 492A) The edges of the separated aponeurosis are held apart by retractors and the internal oblique exposed the muscle fibres crossing the space almost horizontally An opening is made between the fibres of this muscle by a blunt dissector exposing the transversalis

* Ann Sur July 1894 xx 35.

muscle. (*Fig.* 492B.) Both muscles are separated together until the peritoneum is reached. The aperture thus made can be stretched by the blunt dissector and the finger until it is two or two and a half inches long (*Fig.* 493.) The musculo-cutaneous branches of the 12th intercostal nerve at the inner end, and the ilio-hypogastric and ilio-inguinal nerves at the outer end of the space, may be seen and should be carefully preserved. The peritoneum is held up in forceps and incised between them, the forceps are left attached to the peritoneal edge and are very useful when the opening comes to be closed. Full separation of the muscles will give a working space which is enough in

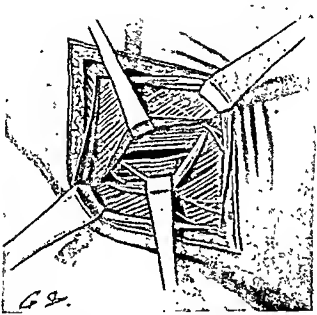


Fig. 492B.—Appendicectomy by McBurney's incision: transversalis muscle exposed by withdrawing external *oblique laterally and internal oblique longitudinally.* The internal oblique and transversalis are usually drawn apart together.

Note 12th nerve above and ilio-hypogastric and ilio-inguinal nerves below.

most cases. If more room is required the separation of the deep muscles may be carried inwards in the same line and the rectus sheath incised. The rectus muscle can then be retracted inwards and the opening in the peritoneum considerably enlarged.

The peritoneum is closed by a continuous catgut suture. The retractors holding aside the transversalis and internal oblique muscles are withdrawn, allowing them to fall together, when they are united by two or more catgut sutures. *Great care should be taken that these sutures include the whole thickness of both muscles.* The aponeurosis of the external oblique is closed by catgut suture. Finally, the skin incision is united according to the practice of the operator. The

operation is designed to prevent postoperative weakness of the scar by avoiding the cutting of muscles Its advocates maintain that less pain is complained of afterwards There is no doubt that recovery is very satisfactory and quick In the great majority of cases even

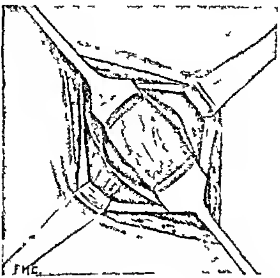


Fig 493 McBurney s incision the peritoneum exposed As a rule the retractors are not required

strenuous work can be resumed at the end of a month *The exposure* is not so good as that obtained by other incisions and it should be reserved for interval cases (group 7) When employed in acute cases the question of drainage is difficult If a tube or tube and gauze is brought directly through the wound a weak spot is very likely to develop and to be followed by hernia

The oblique muscle-cutting incision of Rutherford Morison (Fig 491 c) was first described in *The Lancet** and since that time has been used by the Newcastle school for acute cases almost to the exclusion of any other type of incision It is made parallel with the outer third of Poupart s ligament and the crest of the ilium (Fig 494) The length of the incision depends on the build of the patient and the conditions expected and in this matter technique is helped by accurate diagnosis of the probable position of the appendix If the clinical indications suggest that the appendix is lying in the sulcus on the outer side of the caecum then the incision is made with

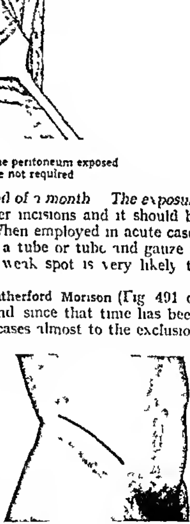


Fig 494 —Oblique muscle cutting incision of Rutherford Morison

* Feb 23 1901 i, 533

its centre just opposite the anterior superior spine and need not be more than 3 or 3½ in in length If, on the other hand, the indications point to a pelvic appendicitis, then it is made further forwards i e from just internal to the anterior superior spine to the outer border of the rectus muscle In any event the incision can be readily extended either backwards or forwards as the condition demands It has the supreme advantage that it leads the surgeon directly down to the

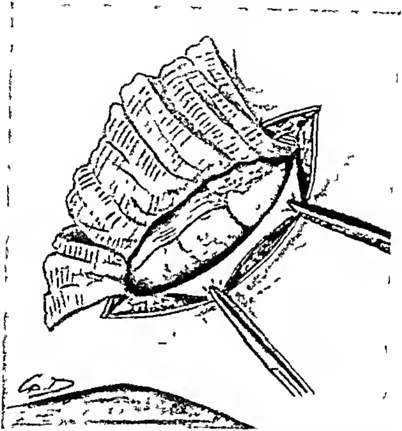


Fig. 495 —The oblique muscle cutting incision exposure of the sulcus on the outer side of the cæcum and protection of the general peritoneum by gauze packing

site of the trouble wherever the appendix is situated, so that it is never necessary to approach a pathological process through the healthy peritoneal cavity By its aid it is possible to deal with all varieties of appendix abscess without troublesome retraction for everything can be done under the guidance of the eye (Figs 495 496) As a rule it is best to avoid cutting the deep epigastric artery, as secondary hæmorrhage from this vessel is not unknown and may be a serious complication Drainage can be most conveniently arranged by bringing the tube from the posterior end of the incision (Fig 497)

In this way the small intestine area is avoided and the risk of ventral hernia greatly diminished (See also p 987)

The choice of incision—The McBurney incision should be reserved for the interval cases Battle's incision will suffice for all the early acute cases, and this or a midline incision should be selected for cases

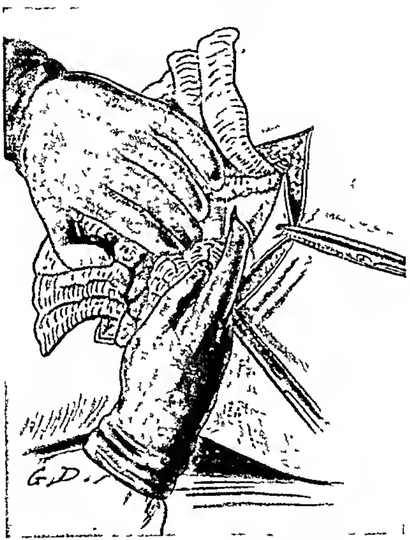


Fig 496—Oblique muscle cutting incision the surgeon is opening an abscess under the guidance of the eye

in which the diagnosis is in doubt and especially in females Except where a general exploration is necessary, the oblique muscle-cutting incision of Rutherford Morison fulfils all the indications and is better suited than any of the others for dealing with appendix abscess

Removal of the appendix in quiescent cases. (Group 7)—Many surgeons believe that the operation should always be exploratory in

interval cases, and for that reason they use one of the rectus incisions from which any part of the abdominal cavity may be examined I prefer to act on a pre operative diagnosis and to be content to examine the appendix region only through a McBurney incision When there is reasonable doubt of the diagnosis one of the rectus incisions is chosen This policy means that the McBurney muscle separation incision is employed in the great majority of cases On opening the peritoneum the cæcum may be seen at once or it may readily be found by introducing a couple of fingers into the wound or using a pair of

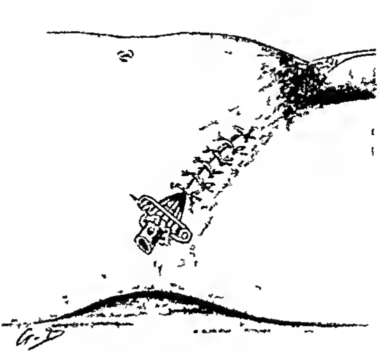


Fig 497 —Oblique muscle cutting incision arrangements for drainage

blunt forceps such as a sponge handle In the first instance just enough of the bowel should be withdrawn to enable the surgeon to get a secure hold Quite often the appendix follows the cæcum into the wound If not the finger may be introduced by the side of the bowel and in many cases the appendix can then be delivered easily and satisfactorily When the appendix is not readily found the surgeon must trace the longitudinal bands towards its base Sometimes this search means bringing quite a considerable portion of the cæcum outside the wound When the appendix is found but does not slip outside easily, it may be grasped with forceps and gentle traction used when as a rule it can be brought to the surface To deal with

the base of the appendix properly, this part of the bowel must be brought completely outside In a few cases, and especially those where there has been a previous abscess, the appendix may be very adherent and may lie behind the cæcum or over the brim of the pelvis or otherwise out of the way In these circumstances the use of narrow-bladed retractors in the wound may enable it to be seen so that the adhesions can be separated under the guidance of the eye When there is difficulty in delivering the organ it may be a help to clamp and divide the mesentery in the first instance and that can sometimes be readily done It is never permissible to pull so forcibly as to risk tearing the appendix across in the depth of the wound or pulling it away from its mesentery Whenever real difficulty is found the incision must be enlarged as already described Once the appendix has been withdrawn, the next step is to deal with the mesentery This may be clamped with one or more artery forceps, divided and then tied in sections, or it may be transfixed and ligatured before division Sometimes a vessel very close to the cæcum manages to escape and must be separately caught and tied The base of the appendix is next thoroughly exposed by gentle traction right up to the bowel, so that the organ appears to be arising at the apex of a cone of cæcum It is then crushed with a pair of artery forceps through its cæcal attachment (Fig 498) The forceps is removed and a ligature applied to the crushed area and firmly tied The forceps is then re applied to the appendix about a quarter of an inch beyond the ligature and the organ is cut across on the cæcal side of the forceps The ligatured stump should be wiped dry with a pledget of gauze and then swabbed with pure carbolic If there is a considerable portion of mucous membrane on the stump it should be trimmed down with scissors Finally the stump is buried with a purse-string suture of No 3/0 chromicized catgut A second suture, not necessarily a purse-string, should be introduced over the first This adds additional security and leaves a perfectly smooth peritoneal surface where the appendix stump was located

The cæcum is then returned to the abdomen and the wound closed in layers In this operation it is not necessary to pack off the peritoneal cavity The exposed bowel should be covered while the stump is dealt with and a gauze swab may be used to prevent the further escape of bowel, but with the separating incision there is little tendency to this The incision has the disadvantage that if the appendix is not easily found and a considerable portion of bowel has to be drawn up through what may be a rather tight aperture in the abdominal wall, it soon becomes distended and congested and it may be difficult to return it to the abdomen without tearing its peritoneal coat or producing a subperitoneal hæmatoma To avoid this trouble the bowel should be replaced in the abdomen as soon as the appendix is found, only so much being left outside as will enable the surgeon to deal safely with the base of the appendix Extruded bowel that has to be returned after it has become distended and congested should

be covered with a large gauze and its contents gently squeezed into the colon in the abdomen. After considerable pressure the surgeon will feel the contents gurgling back into the intestine and, as a result, the bowel will become quite flaccid and can be readily returned through the small incision. The operator must avoid the temptation to use any sharp-pointed instrument to thrust the cæcum back. Any peritoneal tears that may have occurred should be drawn together with a few points of suture. If a considerable area is involved it may be covered and tucked in by using a continuous suture. Whatever difficulties may be encountered in removing the quiescent appendix, it should always be remembered that they will all disappear with proper exposure. I would strongly urge the beginner to use the oblique muscle-cutting incision for his earlier cases and for those where there has been a previous history of abscess.

Alternative methods of dealing with the appendix stump.—American surgeons* have drawn attention to various after troubles that are said not infrequently to result from burying the stump by the purse-string method. It is stated that an abscess may form at the site and may burst into the bowel or give rise to peritonitis or to abscess in the liver. In other cases chronic inflammatory trouble may follow, with persistent pain, tenderness and other signs of peritoneal irritation. As a late result a diverticulum is said to occur at the site, carrying the risks associated with diverticula in general. It is therefore suggested that it is safer and better merely to ligature off the appendix and either divide it with the cautery or carbolize the stump. This technique is used both in quiescent and acute conditions. It is well known that in the great majority of cases this plan is sufficient, but burying the stump ought to provide additional security and does seem to have stood the test of time in the hands of British surgeons. Other plans have been suggested, and it is necessary to warn against simply tucking in the stump without ligature, as deaths from hæmorrhage into the bowel have followed this method.

Operation in acute appendicitis.—The choice of approach is largely influenced by the teaching of the different surgical schools. The vertical rectus incisions have for long been popular but have the disadvantage that if the inflamed appendix is situated anywhere on the outer side of the cæcum it must be approached through peritoneum which is probably uninvolved in the inflammatory process. Further, should it be necessary to leave in a drain, it has to pass through the abdominal wall at a site where hernia is likely, or an independent incision must be made for it. The incisions directly over the appendix region have the great advantage that the site of the disease is immediately exposed when the peritoneum is opened. The muscle-separating incision of McBurney, which is so satisfactory for the quiescent cases, is often most unsuitable for the acute cases. Only rarely can the gangrenous or inflamed appendix be delivered through the limited space available without the risk of its being torn or ruptured and, if it happens to be situated in the pelvis

*[illegible]

or behind the cæcum or far up on its outer side it can only be removed at the expense of much harmful manipulation Further drainage is unsatisfactory and there is considerable risk of infection of the abdominal wall The oblique muscle cutting incision of Rutherford Morison gives the best exposure and has the advantage that it can be extended forwards towards the pelvis or backwards towards the loin as the occasion demands Used in this way it will meet the indications in any circumstances likely to be encountered The experience of many years in large numbers of cases long ago convinced me of the superiority of this incision but a far better testimony to its value is the fact that a succession of assistants have adopted and continue to use it with complete satisfaction In females where there may be doubt about the diagnosis between tubal inflammation and appendicitis or in doubtful cases in the male the midline subumbilical incision should be used

The length of the Morison incision will be governed by the type of case and the build For all but abscess cases and in those of average build an incision about four inches long will give a sufficient exposure In the abscess group (b) and especially in stout people an incision of five to six inches or even longer may be required but it can be so readily enlarged either forwards or backwards that it is not necessary to make it very long in the first instance In making this incision it is important not to carry it as far forward as the deep epigastric artery in the first instance Should an inward extension be necessary it may be carried right up to or even into the rectus sheath but in that case the deep epigastric vessels should be deliberately caught ligatured and divided so that they can retract out of harm's way As soon as the peritoneum is opened there may be an escape of exudate some of which will probably flood the wound As much as possible should be mopped up with gauze or the aspirator may be used The appendix may immediately come into view or it may be felt as soon as the finger is introduced When it is not easily found the operator should trace the longitudinal bands on the cæcum which lead to its base and with this as a guide the organ will nearly always be readily found and can be freed by the finger passed along towards its tip Should the appendix be tucked away under the cæcum or colon it is very helpful to cut through the peritoneal bands and attachments which so often tie the bowel down to the iliac fossa

After this has been done the cæcum may be displaced inwards disclosing the hidden appendix which may pass up behind the colon sometimes in the retro peritoneal tissues Sometimes the mesoappendix is too short to allow the organ to be brought up into the wound In these circumstances it will be necessary to clamp and divide the mesentery Even after this step there are some few cases in which the appendix cannot be readily extruded especially in abscess cases In these circumstances it should be clamped across at its base and divided after which it can usually be separated and delivered by working in a retrograde fashion Of course the proximal end must

be ligatured and tucked into the cæcum either before enucleation or after (Fig 498) Occasionally even this method of removal is difficult or well nigh impossible, and in this small residue of cases the mucous membrane may be enucleated from the thickened and indurated outer coats To accomplish this, the outer coats are incised down to the submucous layer and this "inner appendix" is caught in forceps, traction aided by forceps will usually complete its enucleation The thickened outer coats are left undisturbed

The management of the stump of the appendix has led to a considerable amount of discussion over many years I have always made it a practice to bury the ligatured stump and I believe this gives the

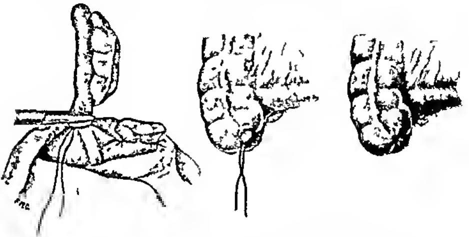


Fig 498 —Appendicectomy by simple clamp and purse string method

best result with the least risk of fæcal fistula adhesion or subsequent trouble In operating in the acute phase it is not always possible to do this satisfactorily because the parts about the base may be so much thickened and indurated In these circumstances, after ligature, the stump may be seared with the cautery, or carbolized, and left exposed but a tube should always be brought from the neighbourhood Gauze should not be employed as a drain, or protective lymph may be torn away when it is removed In many acute cases especially groups (1) and (2), the stump can be buried and the abdomen safely closed without any drain

In the management of the mesentery there is room for different methods When it is not overloaded with fat it can very conveniently be caught in one or more pairs of artery forceps and divided, the tissue in each forceps being separately ligatured It is seldom necessary to use more than three pairs of forceps and quite often a single bite will suffice When the mesentery is very fat it must be divided well beyond the forceps, as there is risk of the vessels retracting and causing what may prove to be a very troublesome hæmatoma in the mesentery and beyond The inflamed mesentery may be so friable that the ligature cuts itself loose In these circumstances the vessels must be

caught again and a ligature on a needle passed back and forth through the mesentery, well above the bleeding site, and tied. When the vessels can be readily seen the mesentery may be transfixed and secured by ligature, but when they are not seen there is a risk of puncturing them and some trouble may result. It is always possible to catch the vessels in the mesentery, but there are occasions when there may be a little bleeding from the area to which the appendix has been adherent. As a rule this is an ooze which will cease on pressure. Occasionally a vessel may require ligature, and sometimes the oozing can only be controlled by packing gauze rather firmly over the site. Such gauze must be left *in situ* and brought out of the wound with the drainage tube. When a gangrenous process extends into the meso-appendix there is a special risk of portal pyæmia and great care should be taken to secure the mesentery well above the affected area.

Drainage requires consideration and does not only concern the security of the ligatured stump. If exudate is thick and abundant, or if there is even a small quantity of pus, it is better to leave in a drain, whereas this is unnecessary if the exudate is clear. Group 3 cases should nearly all be drained. In this group there is a great tendency for infected fluid to collect in the pelvis, and sometimes the lower coils of the ileum may adhere to the brim, shutting off the fluid. In these circumstances it is wise to "sound" the pelvis, when the appendix is removed, by gently separating the intestinal coils, which are only lightly adherent, and introducing the finger over the pelvic brim. Almost invariably a considerable collection of fluid will escape, but if it does not do so it is not necessary or wise to mop out the pelvis or to use the aspirator, for fear of conveying infection and damaging the peritoneum. If infected fluid is found in the pelvis a drain should be passed over the pelvic brim. The best form is a rubber tube about little-finger size; this should be softened by cutting it in a spiral fashion throughout its length. It must be borne in mind that this group furnishes most of the instances of pelvic abscess developing during convalescence. While there is no doubt that drainage of the pelvis prevents this complication in many instances, it may occur in spite of such drainage. The possibility must be kept in mind, especially during the first ten days of convalescence.

In the abscess case the oblique incision proves an enormous advantage because it means that the surgeon will come down directly to the seat of the mischief. On occasion, as soon as the peritoneum is opened pus will be found, but in other cases the peritoneal cavity is free, the abscess being shut off entirely within the abdomen. In these circumstances the general peritoneum is protected by gently packing with gauze over the cæcum, towards the pelvis and towards the right loin. If the abscess is not situated in the sulcus on the outer side of the cæcum it will be found towards the pelvis, towards the loin pouch, or behind the cæcum, and in all probability the guide to its location will be adhering omentum or the distal end of the appendix passing into the inflammatory mass. The peritoneum

having been packed off the abscess must be opened Its wall can usually be broken down by the finger and only on rare occasions will it be necessary to use scissors With the oblique incision the pus runs readily to the surface over the posterior part of the wound and can usually be controlled by gauze swabbing, though no amount of care is likely to prevent some soiling, but the wound usually heals perfectly well in spite of contamination When the abscess has been emptied and dried the appendix may be obvious or may at least be readily found after a limited search Though it is highly desirable to be rid of the appendix and though this can safely be done in a considerable proportion of abscess cases it is not essential for immediate recovery To set out to remove the appendix at all costs causes an unjustifiable increase in the mortality In cases of difficulty it is therefore best not to run the risk of inflicting unnecessary trauma, or spreading infection in attempts at removal which should be postponed to a later intervention during the quiescent period It is in these abscess cases that the perforated appendix is most likely to be encountered, and it is necessary to take great care that the whole organ is removed Not infrequently the appendix is separated into two portions at the site of a perforation It should be very carefully examined immediately after removal so that if there is any doubt about its completeness, search can be made for the remaining part

Perforations near the base of the appendix are often associated with severe general peritonitis (group 4 cases) or with large abscesses Such a perforation may extend into the cæcum and may not be occluded by the encircling ligature of the base of the appendix Great care must be taken to close such holes by suture, and it is wiser to provide drainage In abscess cases an enterolith is sometimes loose in the pus or may be hidden in the recesses of the cavity, and it is well to explore with the finger to make quite certain that no such foreign body remains behind When the omentum is closely wrapped about the appendix or is thickened and involved in the inflammatory process, it can often be separated with ease, and should be preserved and used for packing down into the area after the removal of the appendix When, on the other hand the adhesions are so firm that it can only be separated from the appendix with difficulty, it may be ligatured off and removed with the organ In these circumstances it is important to divide the omentum through the area which is presumably healthy, otherwise there is a risk of displacing septic thrombi which might perchance cause portal pyæmia

In the retro cæcal cases the inflammatory process sometimes spreads to the iliacus or the psoas muscles This may be an extension from an abscess about the appendix or its tip may be directly adherent to the sheath of the muscles and the whole abscess may be situated among the muscular fibres In either case the thickened muscle sheath must be freely incised so that the abscess can be emptied and drained This complication of appendicitis may be diagnosed with confidence when psoas rigidity is present as a symptom When

using the oblique incision all drains are brought out at its posterior end at which there is much less liability to hernia (Fig 497) After the drains have been arranged the omentum when accessible should be pulled down to the appendix site and laid over the drain in the sulcus on the outer side of the bowel The wound must always be carefully closed in layers with catgut the peritoneum with a continuous suture and the muscles in at least two layers by interrupted sutures Chromicized gut should be employed size 3/0 is suitable for the peritoneum and No 1 for the muscles or in muscular men size No 3 It is not wise to overlap the external oblique in the acute cases as that might encourage cellulitis of the belly wall The skin is closed with interrupted sutures of silkworm ¾ of an inch apart The whole idea is to provide ready exit to the surface for discharge should sepsis occur in the wound Where there is gross infection there may be a little localized cellulitis or an abscess may form in the wound part of which has then to heal by granulation Efforts have been made to prevent infection of the parietes by the use of Bipp and now of the sulphonamides but I am not yet convinced that these have proved of much value against the *Bacillus coli* which is the usual organism In the absence of spreading infection which is quite unusual wound healing is most satisfactory and the proportion of weak scars or of definite herniæ is very small and certainly no greater than after any of the other incisions When acute appendicitis is approached through one of the vertical incisions it is necessary to pack off the small intestine very carefully towards the middle of the abdomen and to work along the ileum to the cæcum When the cæcum is freely movable it may be easy to expose it and to draw it forward but should it be tied down then the operation may be very difficult indeed Where there is a collection of infected fluid or a localized abscess about the appendix there is a very considerable risk that the peritoneum will be fouled Free use must be made of gauze swabbing and of the aspirator For drainage it is necessary to make an independent incision in the right iliac fossa or in the right flank Such an incision is sometimes known as a stab wound * this may be made either blindly from without or the surgeon may deliberately cut down on an instrument or a finger pressed against the abdominal wall from within in order to make a definite prominence When only a small drain will suffice it is enough to bring this out through the lower part of the vertical incision but that can only be done with the knowledge that it does increase the risk of incisional hernia

Accidents that may happen during operation for acute appendicitis — The bowel may be torn during the separation of the cæcum or lower end of the ileum As a rule such a tear would only involve the outer coats but if the viscera are much softened by inflammation the lumen may be inadvertently opened There is also the possibility that the abscess may have burst into the bowel and that the opening thus made may be exposed But whatever the cause the defect must be closed in the ordinary way with two layers of suture If

* An [illegible] fortunate expression [illegible] ing the sort of tra[illegible] which ha[illegible] [illegible] very

on account of the softened condition of the bowel the suturing is inefficient there is additional reason for drainage and in these circumstances it is wiser to place a piece of rubber sheeting over the sutured area and to use a rather larger tube than would ordinarily suffice Gauze should not be used for this purpose because when removed it is likely to tear away the lymph which nature throws out by way of repair When only the outer coats of the bowel are torn the mucous membrane may bulge into the rent this should be remedied by drawing the tear together with a few catgut sutures On rare occasions when the lower end of the ileum has been much involved in the inflammatory thickening and œdema it has been mistaken for the appendix and a considerable section of its inner coat has been enucleated under the assumption that the appendix was being isolated for removal If the accident is discovered after only an inch or two of the inner bowel has been separated it may be allowed to retract into position and the outer coat repaired by a few stitches Probably no harm will follow but provision must be made for drainage If anything more than this small amount has been separated—and I once saw a piece of bowel eleven inches in length enucleated in this way—then the only rational way to deal with the accident is to resect the damaged bowel tuck in the cæcal end and make an anastomosis between the upper end and the cæcum or ascending colon

Complications after operation for acute appendicitis—Many complications may follow operation for acute appendicitis In the first few days there may be diffuse peritonitis ileus cellulitis and sloughing of the abdominal wall and chest complications Later occur fæcal fistula pelvic abscess subphrenic abscess obstruction from intestinal adhesions pylephlebitis and last of all persistent sinus and scar hernia

Some few patients complain of indifferent health which is usually attributed to adhesions persisting after convalescence In such cases it is much more likely that the original diagnosis has been at fault and that some other condition such as duodenal ulcer a chronically inflamed gall bladder or a low grade hydronephrosis is the cause

Diffuse peritonitis is generally a continuation of the septic process originating in the appendix Cases of a certain type show a steady downward tendency apparently uninfluenced by the removal of the appendix and appropriate after treatment These are almost always examples of acute appendicitis without limiting adhesions for it is very rare for a case of localized abscess to develop diffuse peritonitis after operation It is very important to differentiate between ileus and diffuse peritonitis as the treatment of these two conditions is somewhat different The subject is discussed at p 1001 It is sufficient to say here that if diffuse peritonitis not existing as such before the operation follows an operation for acute appendicitis active treatment must be instituted on the lines suggested (p 997) but the prognosis must be considered very grave

Cellulitis and sloughing of the abdominal wall—This is a rare com

plication occurring in cases of virulent infection It begins as an acute cellulitis in the neighbourhood of the wound and spreads rapidly in all directions, but chiefly towards the loin and is accompanied by symptoms of acute toxæmia resembling in some respects those of erysipelas It is best guarded against by gentle handling at the operation, by avoiding retraction of the wound and opening up of muscle planes, and, in closing the wound, by taking care that no dead spaces are left and at the same time that the incision is not too closely sutured Treatment consists in opening up the original incision very thoroughly and free incisions into the infected tissues, removing the deep sutures if the process is among the muscles or if the removal of the skin and subcutaneous sutures is not effective When the condition spreads widely and rapidly free incisions into the infected tissues should be made without stint The resources of chemo therapy will probably do much for the case, and should certainly be thoroughly tried Anti-gas gangrene serum may also be used In recovering cases there is often a good deal of loss of tissue by sloughing and secondary hæmorrhage These infections are attended by a high mortality, and, even if the patient recover, much injury may have been done to the structures of the abdominal wall

Fæcal fistula is only likely in cases complicated by abscess If the appendix has not been removed a perforation near its base may be the cause Such cases are readily dealt with by removal of the appendix In other circumstances the condition results from the discharge of an abscess into the bowel, or is the result of necrosis following infection or injury during the operation In the *cæcum* the fistula generally arises as the result of direct extension of the appendicular infection to its wall in the *small intestine* it more usually follows a second operation for pelvic abscess or intestinal obstruction due to adhesions It is an interesting fact that a fæcal fistula from the cæcum is not a very serious complication indeed in many cases it is followed by a rapid improvement in the patient's condition Such a fistula also tends to close spontaneously, but this is not likely if it persists for more than three or four weeks

To close a cæcal fæcal fistula —If minor methods, such as cauterizing the edges of the opening, are unavailing, operation will be required The greatest difficulty may be experienced in cleaning the skin, but fortunately local immunity comes to the surgeon's aid and incisions made in fæcal soiled tissues usually heal kindly The bowel is cleared out by irrigation both from the fistula and from the anus but, as fluid fæces are constantly passing into the cæcum from the ileum the fistula must be controlled before the operation begins This may be done by packing gauze into the opening, or by over sewing the opening after the skin incision surrounding the fistula has been made An adequate elliptical incision is employed, enclosing the fistula at its centre The incision is deepened to expose the peritoneum in its whole length and the latter is opened at the upper end of the incision as far as possible from the fistula, because at this point the bowel is

least likely to be adherent A finger is introduced and the extent of the attachment of the cæcum to the anterior abdominal wall ascertained

The peritoneum is then carefully divided throughout the length of the incision and on both sides of the ellipse thus isolating the fistula The cæcum still with its fistula attached is withdrawn from the wound and the general peritoneal cavity shut off with swabs wrung out in hot saline solution If the cæcum can be lifted out sufficiently it may be lightly clamped to prevent extravasation of its contents but this is *rarely* necessary and may perhaps damage its wall which is very thin and less able to resist even slight trauma owing to previous inflammation

The fistula is then cut away and the resulting opening closed by a double layer of catgut sutures the first passing through all the coats the second burying the first Lembert fashion The cæcum is returned to the abdomen and the parietal incision closed in three layers without drainage

To close a small intestine fistula —The injured intestine may be adherent to the parietes or it may be in the pelvis the fistulous track being long and tortuous For such a fistula there is no alternative but the open method

The operation may be serious as there will be dense adhesions and a definite risk of infecting clean areas The bowel is also very friable and very apt to be torn in the process of separation However it is a well known fact that patients who have suffered from long-standing peritoneal infection have great resisting power and often better results are obtained than are expected The original incision will have to be re opened in its whole length The peritoneum is opened as in the intraperitoneal closure of cæcal fistula Should the track be a long one some assistance can be obtained by passing a probe along it from without The affected loop of intestine which is generally ileum is searched for after packing off the general cavity of the peritoneum and is set free and brought to the surface by gently separating adhesions As in all these operations a free incision good light and gentle manipulation are absolutely necessary When the loop has been brought up it is surrounded with swabs wrung out in hot saline and examined If the opening is small it may be quite safe to close it by simple suture i e if that can be done without narrowing the lumen of the bowel to any extent If the edges are very thick and irregular it may be necessary to excise that part of the intestinal wall and to close the hole with a double line of suture so placed that the gap is closed across the axis of the bowel in order not to reduce its lumen If it seems that excision of the fistulous opening would leave a gap which could not be safely sutured or if the distal segment is much reduced in size an enterectomy with immediate restoration of continuity is the best treatment

Small intestine fistulæ do not lend themselves to extraperitoneal closure chiefly because the intestine is always more or less kinked at

the site of the fistula, and also because of the tendency of the lower distal segment to contract

Obstruction from intestinal adhesions.—A point of interest in these obstructions is that if they co exist with a pelvic abscess, as is often the case, the draining of the abscess may be enough to secure complete relief (*See also* p 882 *et seq*)

Persistent sinus.—This is generally due to an irritating cause, such as the unremoved appendix or a fæcal concretion which has escaped through a perforation Such a sinus may result from the extension of an abscess into the sheath of the iliopsoas muscle When due to the first an operation must be undertaken for the removal of enterolith or appendix This may be very difficult or unexpectedly easy The golden rule applies free incision, good light, gentle manipulation and careful protection of the infective area

For *pelvic abscess*, *subphrenic abscess*, and *scar hernia*, see respectively pp 1003, 1002, and Vol II

Inguinal hernia following operation for appendicitis.—Occasionally a right inguinal hernia has appeared so soon after an operation for appendicitis as to suggest cause and effect Such a hernia has been particularly noticed after the muscle-separating incision of McBurney and the oblique muscle-cutting incision of Rutherford Morison It has been stated that the nerves which govern the nutrition of the abdominal wall in the inguinal region are apt to be injured by either of these incisions On the other hand, this hernia has occurred even when the greatest care has been taken to avoid damage to the nerves It may be that the presence of a very firm scar in the right iliac fossa throws an especial stress on the inguinal region, so that hernia is more likely, especially if there has been some predisposition Certainly this hernia may occur when the appendix scar is perfectly strong and is not usually noticed in cases in which it is a weak or the site of an incisional hernia There is no reason why operative treatment should not be employed In irreducible cases the contents of the sac may be found diffusely adherent to its walls, but they can always be separated with time and care If the muscles look pale and atrophic, fascial sutures should be employed

Results in acute appendicitis.—As in all operations for acute abdominal conditions, the immediate result depends largely on the interval elapsing between onset and intervention It is true that there are a few fulminating cases where operation at any stage seems to be particularly unsuccessful, but these are quite exceptional For statistics to be of any value, cases should be grouped under such headings as "Acute Appendicitis without Suppuration," "Acute Appendicitis with Diffuse Peritonitis," "Acute Appendicitis with Localized Abscess" Some surgeons hold that all should be classified according to the interval elapsing before operation

The following figures from my own practice supply a basis for comparison which has proved practical and useful

Group	—	Cases	Deaths	Percentage
	Acute appendicitis			
1	without peritonitis	159	0	0 0
2	with localized peritonitis	428	4	0 93
3	with flank or pelvic peritonitis or both	230	22	9 56
4	with diffuse peritonitis	96	28	29 16
5	with residual abscess	64	5	7 81
6	with primary localized abscess	446	16	3 59
7	*interval removal*	*1080*	*4*	*0 37*
8	with primary complications	*20*	*9*	*45 0*
	Total	2523	88	3 49

Group 5 consists of cases in which there has been some unlimited peritonitis which has subsided and left an abscess In group 6 the abscess has developed around the appendix wherever situated and has *been localized from the start Group 8 includes cases such as acute* intestinal obstruction and pylephlebitis with appendicitis, hence the high mortality but since an existing acute appendicitis was the primary lesion, they cannot fairly be excluded The classification is made on the findings at the time of operation

If groups 1 and 2 are added together it provides a series of 587 cases of acute appendicitis *with 4 deaths, a mortality of* 0 68, which is just about 2/3rds of *1* per cent *If the cases in group 3 are also added it* gives a total of 817 with 26 deaths, a mortality of 3 18 per cent Groups 1 to 6 inclusive aggregate 1423 cases of acute appendicitis, of all degrees of severity, with 75 deaths, a mortality of 5 27 per cent The great lesson of these figures is that, if cases of acute appendicitis can be operated upon while the disease is still limited to that organ or its immediate vicinity, the intervention can be carried out with a mortality of less than *1* per cent

II. PERITONITIS

Surgery is of value in the following conditions —

Infective Peritonitis

(1) *Local infections*, e g of appendix, gall-bladder, pancreas, Fallopian tubes, ovarian cyst with twisted pedicle, etc

(2) *Perforative lesions*
   (i) Sudden, e g perforated ulcer of a hollow viscus
   (ii) Gradual, e g leaking ulcer or neoplasm of a hollow viscus

(3) *Traumatic*, e g (*a*) Postoperative
   (*b*) Injury to a hollow viscus
   (*c*) Hæmorrhage

Generalized Infection with Peritonitis
(1) *Pneumococcal*
(2) *Tuberculous*

Most types of peritonitis tend to localize, with the formation of adhesions, the low-grade more than the high grade infections, so that the common expressions *localized* and *diffuse* refer to stages in the progress of peritonitis

All surgeons agree that when peritonitis is the result of perforation, operation is imperative When some definite septic focus is the cause operation is of the greatest value and the only question is the stage at which it should be performed On general grounds it should be performed at the earliest possible moment, but opinions differ on the advisability of operating when there is profound toxæmia and great distension Thus, many surgeons operate at any stage after the diagnosis has been made, whereas others maintain that in many cases where forty eight hours have already elapsed since the onset, operation should be deferred in the hope that the infection will become localized It is a matter for individual judgment in the particular case If a rule must be laid down it would be fair to say that if, at the end of forty-eight hours there is no evidence of localization, operation should be undertaken but if localization is beginning or progressing, expectant treatment should be considered Of course a localized abscess requires drainage as soon as it is recognized

Acute Diffuse Peritonitis

Preliminary treatment.—These cases usually arise in association with appendicitis or the perforation of some hollow viscus As soon as the diagnosis is settled and while preparations are being made for operation or for removal to hospital or nursing home the patient should be placed in Fowler s position unless in a state of grave shock Nothing whatever should be given by the mouth If a journey has to be undertaken a dose of morphia and atropine hypodermically should be administered

Pre-operative treatment.—In late cases, as judged not only by the lapse of time but by the degree of pathological mischief reflected in the clinical condition the decision when to interfere depends on the response to treatment Patients who look ill have a dry tongue, a quick pulse, chilly extremities abdominal distension and vomiting are in a desperate state and require prompt treatment Rest in bed, warmth the absence of over-fussy attention and an atmosphere of confidence, are all good to begin with, but the indications are to make up for the loss of body fluids, to provide nourishment, to decompress the hollow viscera to promote excretion and to relieve pain It is usually recommended that these patients should be nursed in the Fowler position, but at this desperate stage they should be allowed to lie in the position of greatest comfort

Because of the vomiting and distension, fluids cannot be given by

the mouth and it is usually best to begin with an intravenous administration of glucose-saline solution If the blood pressure is not too low the intramuscular route may be chosen or sometimes the bowel A careful watch must be kept on the urinary output and for signs of respiratory embarrassment from pulmonary oedema The glucose and saline supply nourishment in the form in which the tissues can most easily use it

To decompress the hollow viscera a stomach tube is of the greatest help This may be of the Ryle or the Wangensteen type which are easily swallowed If this measure does not bring sufficient relief or if uncomfortable distension persists the Miller Abbot tube may be substituted It is not always easy for the patient to swallow this tube and it is necessary to use the X ray to determine that it has gone through the duodenum If it is uncomfortable and causes distress it will do more harm than good and should be abandoned A distended colon suggested by bulging in the epigastrium and flanks may be emptied by the rectal tube which enables flatus that reaches the rectum to escape easily Often a glycerine enema does much more for it may encourage peristalsis in the colon If the glycerine fails a strong salt enema (a handful of salt to a pint of water) may act and if retained it does no harm Small doses (gr $\frac{1}{40}$) of strychnine given hypodermically every four hours stimulate the plain muscle of the bowel and help to restore its tone The output of urine must be watched in the presence of an ample intake too small an output is a bad prognostic sign just as free enuresis is of joyful augury To combat pain there is nothing like morphia but it should not be hastily given nor until the other measures suggested have had an opportunity of proving their worth Pain is not usually very severe but may be persistent and distressing A very small dose (gr $\frac{1}{16}$) of morphia intravenously sometimes has a wonderful effect It can be conveniently administered with a hypodermic into the rubber tube used for the drip This small dose may be repeated every six hours until the patient is completely relieved The indication for morphia is pain and it is often not so successful for mere weariness or mental distress For their relief chloral and bromide gr 30 of each dissolved in water and given per rectum in 4 ozs of milk often works wonders Paraldehyde (1 to 2 drachms) is equally successful but may have rather too lasting an effect it has to be diluted with eight times its bulk of water

To combat circulating toxins is the root of the matter and until the focus can be dealt with it seems rational to employ any specific antitoxic serum For this purpose anti gas gangrene serum has been much vaunted but I have never been convinced of its virtues in peritonitis Convalescent serum would meet the indications if we could ascertain the prevailing organisms and a polyvalent convalescent serum would appear to be a desideratum of the first importance The role of chemotherapy in peritonitis is not yet sufficiently established but is promising If the bowels move it is a good omen but really of secondary importance and strong or repeated purgatives are harmful

When to operate—If improvement follows these measures the surgeon must watch for the favourable moment to intervene surgically That may come in six or twelve hours or more but if at any period after six hours improvement seems to have come to a standstill any surgical intervention felt to be necessary must be carried out In such cases only the minimum interference is permissible and will probably consist in merely opening a localized abscess or introducing a tube into an unlimited collection in the peritoneal cavity

After such an intervention the surgeon must not make the mistake of hastily discontinuing the measures directed to combat the peritonitis

In some cases recovery from the peritonitis is so complete that it need not be interrupted for any sort of surgical intervention though there is always a stage when the whole problem must be reviewed so that steps may be taken to prevent the recurrence of a condition which has brought the patient so near to the grave

Operative technique—The surgeon must realize that ground may be easily lost and for that reason any proposed surgical intervention should be conducted with special care There must be no disturbing preparation and anything that is required in the way of cleansing the abdominal wall must be done in the theatre If a differential diagnosis can be made the incision is planned so as to provide the most ready access to the organ at fault otherwise the midline sub umbilical incision is indicated (Fig 191 D) In general terms it may be laid down that the actual cause of the diffuse peritonitis whether it be a perforated gastric or duodenal ulcer a gangrenous appendix or gall bladder or whatever else *must* be dealt with if recovery is to be achieved so that further infection from that source may be prevented Whereas drainage alone will be life saving in an inflammation of the appendix the gall bladder the pancreas or the pelvic organs it is necessary actually to close perforations of the stomach or duodenum I have never seen a ruptured ulcer recover when the operation was limited to the drainage of an unlimited peritoneal extravasation

This observation does not apply to the incision and drainage of peri gastric or peri duodenal abscesses from leaking ulcers where nature has already completed the process of localization Details of the operations required will be found in the appropriate sections

After the primary cause has been dealt with two questions have to be answered (1) Shall the peritoneal cavity be flushed ? (2) Shall the peritoneal cavity be drained ? Both these questions are being answered more and more in the negative

Flushing the peritoneal cavity—The objections to this procedure are many

It is apparent (1) that to flush out so complicated a cavity satisfactorily evisceration is often necessary—a step which involves much handling and exposure (2) that this very handling may convey infection to parts possibly free from infection (3) that flushing lowers the blood pressure (4) that it is open to question whether washing

away gross infection really makes any difference, and (5) that the peritoneum, if left to itself, has great power of recovery Though flushing probably makes little difference to the mortality one way or the other, it appears to add to the incidence of intraperitoneal complications At the present time very few surgeons flush the peritoneal cavity, and then only in such cases as perforated gastric ulcer where gross food particles may be present The "toilet" of the peritoneum is usually limited to gentle swabbing in the neighbourhood of the affected organ, in order to remove collections of pus or other fluid, and aspiration of fluid from the pelvis by suction through a tube introduced through a suprapubic incision Exploration of the pelvis is necessary in most acute abdominal conditions, as large quantities of fluid may gravitate there and give no sign of their presence unless routine investigation is undertaken

Drainage —Where there is free fluid, which might be harmful, and which cannot be entirely removed, there is a natural inclination to drain Of late a reaction has set in against drainage, and the following objections have been raised, viz (1) that the peritoneal exudate may be beneficial rather than harmful, (2) that the peritoneum is well able to control infections if the primary focus is dealt with, (3) that the drainage tube generally has to work against gravity, (4) that in a very few hours the tube becomes walled in with adhesions and therefore drains only its own track, and (5) that the presence of a tube tends to form adhesions, may determine an intestinal obstruction, and is generally dangerous

These objections require consideration

(1) The character of the peritoneal exudate varies according to the length of time of bacterial invasion Its naked-eye appearances vary from clear to slightly turbid or purulent fluid or fluid in which masses of lymph are floating In perforation of the stomach or duodenum there may be gross food particles The tendency to localization by adhesions may result in one collection of fluid being serous while another is purulent The cellular characters of the fluid vary widely, and active phagocytosis may or may not be present There is no doubt that the fluid first poured out by the peritoneum is protective, but at a later stage many free bacteria are found in it It was suggested by the late Sir David Wilkie that an immediate bacteriological examination at the time of operation was of great value, not only in prognosis, but also in deciding the question of drainage A film of the fluid is made and is stained and examined under an oil immersion lens in the theatre The organisms may be found in the leucocytes or free in the fluid, the former location is taken to indicate good resistance, the latter bad and Wilkie suggested that drainage was then advisable

(2) There is no doubt that the peritoneum has great powers of resisting and overcoming infections, indeed, if it had not these powers, we should have few successes to record

(3) That drainage assisted by gravity has many advantages is seen in the rapid clearing up of a pelvic abscess opened *per rectum* or *per vaginam* But fluid does drain from the pelvis by a tube placed through a suprapubic wound even though it is against gravity Tubes placed among the intestinal coils are worse than useless The gauze drain also is inefficient and leads to the formation of adhesions and " pocketing " It has been suggested that the pelvis may be drained adequately from the front if the patient is prone This has many disadvantages from the patient's point of view, and can rarely be maintained for a sufficient length of time to be of much value

(4) The statement that the tube is walled off by adhesions in twenty-four hours and thereafter drains only its track is not entirely true The amount of fluid which may sometimes drain away during the first few days cannot all come from a narrow track

(5) That the presence of a tube may lead to intestinal obstruction or even to fæcal fistula is true, but only if it is left *in situ* for too long Only one tube should be used, and it should extend to the floor of the pelvis It should be removed or shortened in forty-eight hours, or as soon afterwards as the character of the discharge will permit As soon as the discharge is serous drainage may be discontinued altogether

To sum up the question of drainage in diffuse peritonitis, it may be said that the earlier the cases are operated upon the less the need for drainage Perforations of stomach and duodenum can usually be treated without drainage and cannot be classed with the appendix perforations Serous (non-turbid) exudates do not need drainage unless there is a tendency to localization by adhesions If drainage be used, one tube only should be inserted, and that should reach to the floor of the pelvis Fowler's position renders other tubes unnecessary Some surgeons still prefer a glass tube long enough to reach to the floor of the pelvis, its lower 2 in perforated by many small holes (Keith's tube) The advantages over a rubber tube are that it is easily inserted, it cannot get kinked, and the holes are numerous and small and not likely all to become obstructed by lymph After twenty-four or thirty-six hours such a tube can be replaced by a rubber tube or strip of rubber if drainage cannot be dispensed with altogether

In most situations rubber drainage-tubes are the most generally useful, but they should always be soft It is better to soften a tube by cutting it in a spiral fashion along its length rather than by making lateral holes Omentum or even small bowel is very apt to find its way into holes and may become strangulated, and may be withdrawn from the abdomen when tubes are removed To reduce the liability to this accident it is wise to turn the tube round once or twice every day Rubber sheeting such as dentists use, is convenient when there is no actual collection to be drained away and it is merely a question of providing a track to the surface Very often, leaving a drain in an appendix case seems to prevent suppuration in the parietes even if it does not materially affect the progress of the peritoneal condition There is much to support the view that the presence of a foreign body

like a tube in the peritoneal cavity tends to set the flow of exudate in its direction

After-treatment.—The announcement by J B Murphy at the British Medical Association meeting at Toronto in 1906 of his method of treating peritonitis revolutionized the conduct of these cases and led to an immediate improvement in results The main features of his method were the adoption of the Fowler position (the patient being supported in a sitting position at an angle of 45° to the horizontal) drainage of the pelvis and the continuous administration of normal saline solution by the rectum at a slow even rate (Murphy s drip)

Fowler s position and the administration of saline per rectum have been universally adopted The question of drainage has been discussed above In other details the after treatment is conducted on the lines indicated for pre-operative treatment (p 997) What is said about meteorism (p 1004) may also be applicable

Complications—Subphrenic abscess of the intraperitoneal type as a complication of diffuse peritonitis is seen most commonly after gastric and duodenal perforations though it occurs occasionally after acute appendicitis Extraperitoneal subphrenic abscess does not follow diffuse peritonitis but may be seen after a retrocæcal appendiceal abscess

There is no doubt that the incidence of subphrenic abscess has been much reduced by the adoption of Fowler s position in the after treatment and by the abandonment of irrigation of the general peritoneum Its chief danger lies in the difficulty of diagnosis leading to delay in treatment

Diagnosis depends on recognizing the importance of early slight chest symptoms and signs Examination by the fluorescent screen is most valuable Whenever the condition is suspected repeated examination and careful watchfulness are essential The exploring needle is often the final arbiter but it must be of sufficient length and bore and used with great circumspection When the surgeon has good reason to suspect such an abscess the exploration is better done on the operating table so that the needle may be left *in situ* as a guide and the operation proceeded with there and then

Treatment—There are three routes for *drainage*—(1) from above transpleural through the diaphragm (2) from below by incision in the hypochondrium and (3) from behind after excision of the 12th rib The avenue to be employed is dictated by the situation of the abscess

(1) *Steps of transpleural operation*—The patient should be turned over to the sound side as little as possible consistent with a satisfactory exposure of the area of operation as it is important to avoid restricting the movements of the sound lung An incision 4 in long is made over and in the long axis of the 9th or 10th rib with its centre over the mid axillary or posterior axillary line The rib is resected subperiosteally for the whole length of the incision The rib chosen must not in any

case be higher than the 8th, or the next step may be impossible A clean cut incision is made through the periosteum and the pleura is opened The diaphragm will present, and, if it is pushed up by the abscess, it will be easy to suture its upper surface to the incised parietal pleura (*see* Fig 408, p 764) In this way the pleural cavity is shut off The diaphragm is then incised and the abscess opened A large drainage tube is inserted and the wound partially sutured

(2) *Drainage from below* —This operation, of less general value than that just described, is carried out through an incision, parallel with the rib cartilages, in the right hypochondrium beginning just outside the linea semilunaris and extending outwards for 3 in The edge of the liver will probably be adherent to the parietal peritoneum, the general cavity in the vicinity being occluded The abscess is opened by separating the adherent liver from the parietes

(3) *Drainage from behind after excision of the 12th rib* —This is the method associated with the names of Ochsner and Graves An incision is made along the length of the rib, after its removal a transverse incision is made through the attachment of the diaphragm The retroperitoneal tissue is opened above the kidney The abscess is found by working upwards and inwards with the finger (*see* p 764)

Pelvic abscess —Occasionally, after operation for diffuse peritonitis a secondary abscess forms in the recto vesical pouch or in the pouch of Douglas, either as the result of inadequate drainage or because an infected area has become shut off by adhesions The characteristic features are pain, tenesmus with passage of mucus, patulous anus and a rounded tender swelling bulging the anterior wall of the rectum within easy reach of the finger

These abscesses may be drained from above or below, the latter route being by far the most satisfactory

Drainage from above —This is generally done through the original incision, adhesions being gently separated by the finger until the abscess is reached The operation is not without danger, owing to the risk of re-infecting the general peritoneal cavity or doing some injury to the intestinal coils forming the abscess-wall Of these the latter is the more serious and a small-intestine fæcal fistula is not an infrequent sequel

Drainage from below —As the abscess increases in size it comes into close relation with the anterior wall of the rectum and tends to point in this situation It may rupture spontaneously into this part of the bowel

Drainage can be effected either through the rectum or, in married women through the posterior vaginal fornix The latter avoids the risk of fæcal contamination, but in practice this risk can be dismissed and the rectal route is generally chosen and is in every way satisfactory It should always be used when the abscess presents per rectum

The rectum is usually empty as the result of tenesmus, but if not it must be thoroughly cleared by enemata and irrigation The patient

is placed in the lithotomy position, the buttocks being drawn well over the end of the table It is imperative that the bladder be empty, and if necessary a catheter should be used on the operating table A short Kelly's rectal speculum is inserted and at its extremity the front wall of the rectum is exposed and the site of the abscess defined The presence of the abscess must be confirmed by the exploring needle and syringe When the pus has been demonstrated the needle is left *in situ* and a pair of sinus forceps or a knife is then passed along by the side of the needle and through the rectal wall into the abscess (Fig 499) There is nothing gained by making the incision in any special direction nor is it necessary to attempt to make a valvular opening The opening is sufficiently enlarged to allow the passage of a little finger-size drainage tube This should be long enough to extend beyond the anal margin to which it should be attached by a single silkworm gut suture The abscess cavity does not require emptying by pressure from above nor should it be irrigated The tube may be removed in about four days for by that time the track is well established Discharge ceases quickly, and it is characteristic of these cases that recovery is rapid As the small intestine is pushed up by the gradual collection of fluid in the pelvis there is little risk of injury but as the abscess contracts the small intestine is drawn down to the floor of the pelvis where it may become kinked and obstructed When the abscess is a complication of appendicitis an operation for removal of the offending organ must be considered As a general rule subsequent laparotomy should be postponed for six or more weeks

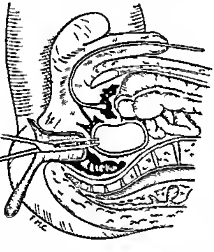


Fig 499 —Opening a pelvic abscess using Kelly's short speculum and sinus forceps

Meteorism (paralytic or adynamic ileus) —Paralytic ileus is a condition usually supervening on septic peritonitis, in which intestinal obstruction occurs not as a result of a mechanical block but from paralysis of peristalsis It usually appears twenty four to forty-eight hours after operation and presents the two features of intestinal obstruction and toxæmia There is cessation of the passage of gas and fæces, very often accompanied by abdominal distension Colicky pain is absent but the distension causes great discomfort Regurgitant vomiting of the typical dirty brown fluid is common but fæculent vomiting is rare The face becomes drawn and anxious, the tongue dry, the pulse and respiration rate steadily increase, and pulse tension becomes progressively lower Restlessness develops and thirst increases as toxæmia is established By the time this stage is reached probably

every method has been tried to re-start peristalsis and to evacuate the bowel

Rational treatment can only be based on the assumption that there are certain ætiological factors with which the surgeon has to deal Toxæmia, the result of the absorption of bacterial products either from the peritoneum or from the bowel, is probably the most important factor Exhaustion of the neuro muscular mechanism and loss of tone of the muscle of the bowel wall, as the result of distension, are other factors Loss of fluid and chlorides, the consequence of vomiting and hyper-secretion into the bowel are also very important A possible psychological feature must not be overlooked, for the patient may be anxious because vomiting persists, or the bowels do not act, or natural sleep is denied him This state is often increased by the undisguised apprehensive anxiety which is sometimes allowed to surround the sick-bed

General management—What has already been said about the treatment of peritonitis (p 997) applies to this condition If we only knew of some specific antitoxin it would be the sheet anchor of treatment, but unfortunately there is much doubt about the efficiency of any of the sera at present known At the outset there can be no harm in administering a purgative it is only the repeated use of purgatives which prove ineffective that is so physically and mentally distressing In this condition nothing equals castor oil but it must be properly administered * Should the oil be vomited, then calomel may be tried Three grains are given in divided doses, half a grain every half hour this is often efficient In either case if there is no result an enema (glycerine ℥ij or soap and water Oj) should be administered four hours after the oil or an hour after the last dose of calomel

If the toxins cannot be cleared out by the bowel or neutralized they must be diluted, and excretion by the kidneys promoted These objects are attained by an abundant intake of fluid Exhaustion calls for food and stimulant Tissue nourishment is supplied by intravenous chlorides and glucose, and stimulant may take the form of small doses of strychnine hypodermically Patients who have been accustomed to alcohol should not be denied their favourite fillip, for a very serious illness is not the time for the blue ribbon propaganda of the temperance advocate The decompression of the intestines to mitigate the harmful distress of distension and to encourage the return of tone to the bowel wall is most helpful, and it is particularly in these cases that we may come to rely more and more on the Miller-Abbott tube But if that apparatus is not available, the stomach tube can do a great deal

When the viscus has been emptied and confidence in the epigastrium restored, the patient may be allowed small drinks if thirst is insistent Generally speaking, very hot drinks are better than cold, the practice of giving ice to suck has no saving virtue whatever In these cases

* A full ounce is the proper dose The oil and the medicine glass should be slightly warmed and should be rinsed out with brandy or whisky A little is left in the glass the oil is carefully poured in and about a teaspoonful of the spirit is poured on to the surface of the oil The addition of a little orange or lemon juice makes it almost delicious!

nature cries out for sleep, and this is always most beneficial. The measures detailed may bring slumber, but if they do not and drugs are necessary, it should be remembered that combinations of sedatives may act well. Aspirin gr. 10 crushed up with gr. ¼ of morphia given as a powder is often successful. If the route by the mouth is not considered advisable, pot. brom. gr. xx with aspirin gr. xx given in emulsion per rectum is useful and may be combined with a very small (gr. $\frac{1}{12}$) intravenous dose of morphia. Patients should be encouraged to court sleep in every possible way; for a few minutes every now and then may mean in the aggregate quite a refreshing slumber. The idea of fighting sleep during the day in the expectation that at night Morpheus will oblige is fallacious. Most patients derive comfort from warmth to the abdomen and it may do more than merely soothe, for sometimes intestinal movements are stimulated. The inhalation of 95 per cent. oxygen is certainly helpful and may be given with a proper face mask for three hours out of four and continued in that way for 24 hours. When the measures outlined entirely fail, spinal anaesthesia may be tried, but although sometimes the result is dramatic it is more often disappointing.

When all efforts are unavailing and the condition is deteriorating as shown by a rising pulse, increasing distension and continued intestinal regurgitation, the question of draining the intestine externally will have to be considered. In appendicitis so many cases improve after the spontaneous development of a fæcal fistula that nature's plan may be imitated. Not infrequently the original incision is over the cæcum which is adherent to the parietes, making it safe to open that part of the bowel at the bottom of the wound after removal of some of the sutures. If this is followed by a copious discharge of intestinal contents, the good effect may be dramatic. Should there be no result, flushing the cæcum with very hot water may produce an outpouring, or a catheter may be passed along the ileum and the small bowel irrigated. If these measures fail, the surgeon has the choice of making a formal cæcostomy or enterostomy or opening the abdomen for exploration and to effect an anastomosis between the small bowel above an inflammatory lesion or localized paretic area and the unaffected bowel beyond.

Cæcostomy.—The condition of the patient does not allow an elaborate ritual and local anaesthesia should be used. If a general anaesthetic is necessary, gas-and-oxygen is far the safest. An incision is made as for appendicectomy or, if an appendicectomy has been the first operation, the wound is re-opened. The subsequent steps of the operation are as described at p. 890. The tube from the cæcum is led through the dressings and connected to a tube leading to a receiver. If improvement is to follow it does so at once. The tube may be removed at the end of a week or ten days. When the method shown in Fig. 780 is employed the opening may be expected to close spontaneously in two to four weeks after the removal of the tube.

Enterostomy.—If it be decided to drain the small intestine, the site for the opening should be as low as possible to guard against the risk

of starvation by too great a loss of intestinal contents and absorbing area. Local anæsthesia or gas and oxygen should be used. The subsequent steps of the operation are as described at p. 906. After immediate drainage of the intestine has ceased the bowel may be washed out with saline solution. Though this is a life saving operation it has the grave disadvantage that a fæcal fistula may form high up in the intestinal tract. The greatest care is necessary to prevent excoriation of the skin and painting with white of egg or milk is helpful.

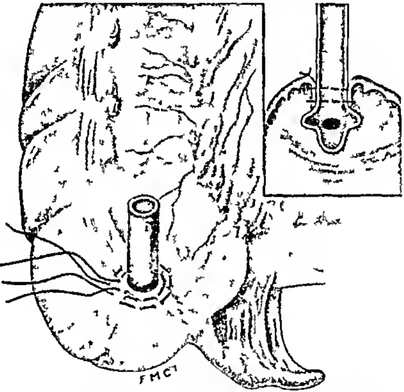


Fig. 500.—Cæcostomy by purse string invagination. A de Pezzer catheter is a very convenient form of tube.

If there is copious persistent escape of intestinal contents the fistula must be closed as soon as possible.

Short circuiting.—To avoid the formation of a fæcal fistula and at the same time to overcome the obstruction and drain the upper tract it has been proposed to anastomose the intestine above to some part of the intestine below the paralysed part. This method of treatment was first brought before the profession by Sampson Handley in 1915. He names the associated condition ileus duplex and recommends that an anastomosis be made between the ileum above the paralysed part and the colon, preferably the cæcum, and that a safety-valve be provided by tying a self retaining catheter into the cæcum at the same time.

From time to time he has reported successes in cases in which this method has been employed but it has not been generally adopted But in any case these operations are only to be looked upon as incidents in the management of the condition and the general measures already detailed must be continued until recovery seems assured

Pneumococcal Peritonitis

Pneumococcal peritonitis usually occurs in *female children* under ten It may be acute (diffuse) or chronic (encysted) and it may be primary or secondary to some focus elsewhere especially pneumonia In the acute form it presents most of the characters of an acute diffuse peritonitis and it is *almost impossible to* make a differential diagnosis before operation The distinguishing features are (1) the presence of some other infective focus especially pneumonia (2) onset with rigors or herpes labialis (3) pain vomiting and *diarrhœa* (4) early free fluid (5) marked leucocytosis (6) preponderance among females and children The temperature does not run high and if the patient is going to recover or to reach the chronic stage the symptoms gradually subside over a period of twelve to fourteen days

Should the chronic stage supervene *an abscess forms painlessly* and localizes below the level of the umbilicus The diarrhœa ceases but the temperature fluctuates and there is marked loss of weight Finally if untreated the abscess usually discharges at the umbilicus resulting either *in recovery* or *in secondary infection* when *death may follow*

Whether the diffuse and the encysted types are merely stages in the same disease or whether they depend for their differentiation on strains of pneumococcus of varying virulence is a question not yet decided *If we could be sure* that every diffuse-type case had a chance of becoming encysted there would be a great deal to be said for deferring operation

In practice it is less harmful to open the abdomen in this disease with little hope of improvement *than it is* to miss the opportunity of removing an acutely inflamed appendix complicated by diffuse peritonitis

Technique —In the acute cases the abdomen is better opened over the appendix region so that if that organ is at *fault it can* be readily removed *Thick slimy non-offensive exudate is characteristic of* pneumococcic infection Drainage is better avoided when the exudate is very watery and the coils of intestine distended In other circum stances or if there is the slightest *suspicion of an appendicular origin* a drain is essential In the chronic localized form a pointing abscess near the umbilicus should be incised there in other cases a midline incision below the umbilicus will be the most direct route to the collection *Abscesses in this type of peritonitis do not tend to point per rectum* Drainage by tube of forefinger size is all that is required In the very ill patients with marked constitutional disturbance chemo therapy may be helpful just as blood transfusion may be so useful in the debilitated chronic case

Results—The diffuse type has been attended by a deplorable mortality and further experience must be awaited as to the influence of the newer drugs of the sulphanilamide group The cases in which a localized collection can be opened and drained do very well

TUBERCULOUS PERITONITIS

Of the three types of tuberculous peritonitis the *ascitic* the *fibrous* or *adhesive* and the *ulcerous* only the first is usually considered amenable to surgical treatment If operation has to be done in either of the other types it is undertaken rather with a view to clearing up a diagnosis or dealing with a complication generally intestinal obstruction than in the hope of effecting a cure It is quite possible that the so called *ulcerous* type is really the final stage of a caseating mesenteric gland tuberculosis and intervention to be successful must take place at a much earlier time It seems certain that operations in these later stages do more harm than good they are often followed by fæcal fistula and death and although there are brilliant exceptions the object aimed at—namely the relief of intestinal obstruction—is not often attained In the *fibrous* type results are better poor as they are and there is a chance of relieving obstruction if the area affected is more or less localized It is as well to say definitely that in the absence of intestinal obstruction the value of an operation to cure cases of either of these two types is very doubtful In the *ascitic* type an exploratory laparotomy is often followed by complete recovery and is attended by a very low mortality

In cases that have been for long at a standstill the rapid improvement which may follow surgical intervention fully justifies the use of laparotomy in this disease None the less operation should only be regarded as an incident in the management and those general and hygienic measures which tuberculosis always demands must be continued for long afterwards

Technique—The operation consists in a median sub umbilical laparotomy the release of fluid and closure without drainage The peritoneum should be sewn up with absorbable sutures and the rest of the abdominal wall in one layer with through and through silkworm sutures Layer suture with catgut seems to encourage the development of tuberculosis in the wound The Mayos report good results after removal of tuberculous Fallopian tubes in adults but this step is not considered advantageous at any rate as a routine in this country

In the *adhesive* type the mere opening of the peritoneal cavity sometimes starts the curative process Quite often cases that have been at a standstill or even going downhill begin to improve at once and go on to complete recovery In this type the surgeon must resist the temptation to separate adherent coils of intestine for not only is this step unnecessary but it is very likely to be followed by fæcal fistula

Contra-indications—Operation should not be advised until the patient has had the chance of a thorough trial of conservative measures

under the best conditions obtainable. A well arranged and supervised anti tuberculosis regimen is an essential part of the after treatment of cases subjected to operation. In cases with generalized or pulmonary tuberculosis or with evidence of tuberculous enteritis, interference is useless.

Results.—In comparing results obtained by medical and by surgical treatment, the after-histories have not been carried far enough to allow more than a speculative estimate. A considerable number of the cases go rapidly downhill under medical management and surgical intervention will not save them. But cases that improve considerably under a medical regimen, and then come to a standstill, often recover completely after laparotomy. Rapid loss of weight and diarrhœa are of very grave prognostic import.

TUBERCULOUS MESENTERIC GLANDS

Operation may be necessary for tuberculous glands in the mesentery which are giving rise to symptoms or complications. These glands *generally occur in the mesentery of the lower ileum or the ileo-colic angle*, and are probably infected with tubercle bacilli from milk, after resistance has been lowered by undetermined causes. They may be considered, therefore, as a local condition comparable in many respects with tuberculous glands in the neck. They occur in three forms, which are merely variations in degree. In the *first* stage the gland is enlarged but presents no unusual appearance, and its serous covering is not affected. In this stage symptoms may be complained of, chiefly the characteristic short-lived colicky pain, but complications other than peristaltic anomalies do not occur. In the *second* stage caseation is present, and the gland may be transformed into a large collection of pultaceous material surrounded by a thin walled capsule. It is this stage which is dangerous, for the peritoneal covering becomes affected and adhesions may form between neighbouring glands or between the gland and a loop of intestine. Or the capsule may give way, flooding the peritoneum with caseous material, or more gradually a condition may arise which is indistinguishable from the so-called ulcerous type of tuberculous peritonitis. The *third* stage, of calcareous degeneration, is a quiescent stage in which the peritoneum is intact over the gland, and complications are less likely. The stage which justifies operation, therefore, is caseating glands, and that alone. It must be remembered that usually all three stages are present together in cases of long standing.

Complications.—As complications are a very important "risk" in these cases, it is as well to consider their frequency. In a paper based on 50 cases, read before the Medical Society of London,* H. W. Carson reported an intestinal kink in 5 cases of 39 with "typical" symptoms, and in the 11 cases with "atypical" symptoms there were 3 cases of

* *Med Soc Lond Trans.*, 1918 xli, 220

intussusception and 5 cases of other types of intestinal obstruction, so that in the 50 cases there were 13 instances of actual or potential obstruction, in one case causing the death of the patient G H Colt and G N Clark* only encountered 13 examples of obstruction among 239 cases reviewed

Indications for operation.—Not infrequently, attacks of abdominal pain attributed to tuberculous glands in the mesentery are really due to mild recurrent appendicitis For this reason unless there is some contra-indication such as the *presence of active tuberculosis elsewhere*, exploration should usually be advised It is something of a tragedy to condemn a patient to an antituberculous regimen or to some degree of invalidism when so simple an intervention as removal of the appendix may cure But the converse is true and when patients are not cured by removal of the appendix there is a tendency to attribute residual symptoms to the tuberculous glands which may have been discovered at operation The accidental discovery of calcareous glands on X-ray examination does not in itself justify operation but laparotomy should certainly be considered if the patient is suffering from symptoms not otherwise explained In certain circumstances the question arises whether the removal of the glands will bring about cure, the late Mr Carson advocated removal and his practice is followed by G H Colt (*vide supra*)

Technique.—The abdomen is opened in the midline below the umbilicus, and the mesentery is examined beginning at the ileo-cæcal junction If the conditions are such that intestinal obstruction appears likely bands or adhesions may be dealt with but the surgeon must always remember that as a result the lumen of the bowel may be opened and must be very carefully repaired A single well-localized active-looking caseous gland certainly invites removal, but several such glands adhering or forming a large mass are better left alone The glands cannot be shelled out but must be removed by dissection, the whole gland being cleanly excised with the knife It is not advised to incise and curette though this may be necessary when glands burst during attempts at removal or are especially adherent After removal the greatest care must be taken to sew up the incision in the serosa In some cases, where the latter is adherent to both surfaces of the gland the removal leaves a hole in the mesentery, and this should be closed Great care must be taken not to puncture or otherwise damage the mesenteric vessels Jamieson and Dobson† give warning of the close relationship of the ileo-colic chain of glands to the ileo colic artery and vein

In rare instances it may be necessary to resect a portion of intestine This necessity will especially arise when a considerable mass of glands abuts on the mesenteric border of the intestine In these circumstances the bowel may be stretched over the gland or may be kinked or narrowed or ulcerated at this point Care must be taken to see that

* *Surg Gyn and Obstet.*, Dec 1937 lxv 771
† *Lancet* 1907 i 1141

the glands do not extend up to the root of the mesentery as this would entail an unnecessarily large resection When resection seems unwise a short circuit may be substituted with confidence In many cases the glands become quiescent after mere opening of the abdomen and this should be borne in mind when their removal would entail a severe operation In every case the intestine is examined for ulcers or kinks and a general survey undertaken of the abdominal viscera for other evidences of tuberculosis The appendix should always be removed and the abdomen closed without drainage Adhesions are apt to follow intervention in these cases and Colt recommends that the abdomen should be filled with saline at the conclusion of the operation Catgut is used throughout for the peritoneal sutures with through and through silkworm gut for the other layers

If complications are present they must be treated on general principles In obstruction it is useless to make an artificial anus proximal to the obstruction and an anastomosis short-circuiting the mass of glands will probably be the best means of relief

Results —The operative mortality is about 5 per cent but that includes the cases complicated by intestinal obstruction Of those who recover the majority are relieved of their symptoms though in a small proportion tuberculosis develops elsewhere

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